EFFECT OF THE ROTATING BLADES ON THE STABILITY OF FLOATING WIND TURBINE

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CIVIL ENGINEERING

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

____

(Dr Montasir Osman Ahmed Ali)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
September 2017

CERTIFICATION OF ORIGINALITY

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, except as specified in the references and acknowledgements, and that the contain of the study have not been undertaken or done by unspecified sources or persons.

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(SYED AMIR ADAM BIN SYED ZAINUDIN)

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Last but not least, I am highly indebted to my family for the understanding and the support throughout my life.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

ABSTRACT: The objectives of the proposed study is to study the effect of rotating blades on the stability of floating wind turbine. The rotating blades or can be called as gyromotion effect had resulted in various of effect towards the stability of floating wind turbine such as that can be seen with human eyes are pitch, yaw, surge, roll, sway and heave, the paper will briefly summarise the background of floating wind turbine and the methodology used to analyse and compute the effect of rotating blade or gyromotion towards the stability of floating wind turbine by using a simulation software which is Star CCM that can simulate the real life time event in order to analyse the effect of the rotating motion towards the stability of the structure. The data used in the study will be from previous researches that have been made.

1.1 Background of Study

Global warming has become worst days by days and fossil fuel depletion become more obvious. These encourage all the researchers to come out with a new type of energy which can be renewable and environmental friendly. It is well known that one of the main sources of renewable energy come from the vast marine space (Nihei.Y, 2012). One of the sources from the offshore which is the offshore wind resources is presumed to be one of the clean and renewable energy. Since the vast marine space do not have any topography, thus the wind produced on the sea much greater than the one on shore. Floating wind turbine main function will be harnessing the wind produce on shore into power efficiently and safely manners (Nihei.Y, 2011).

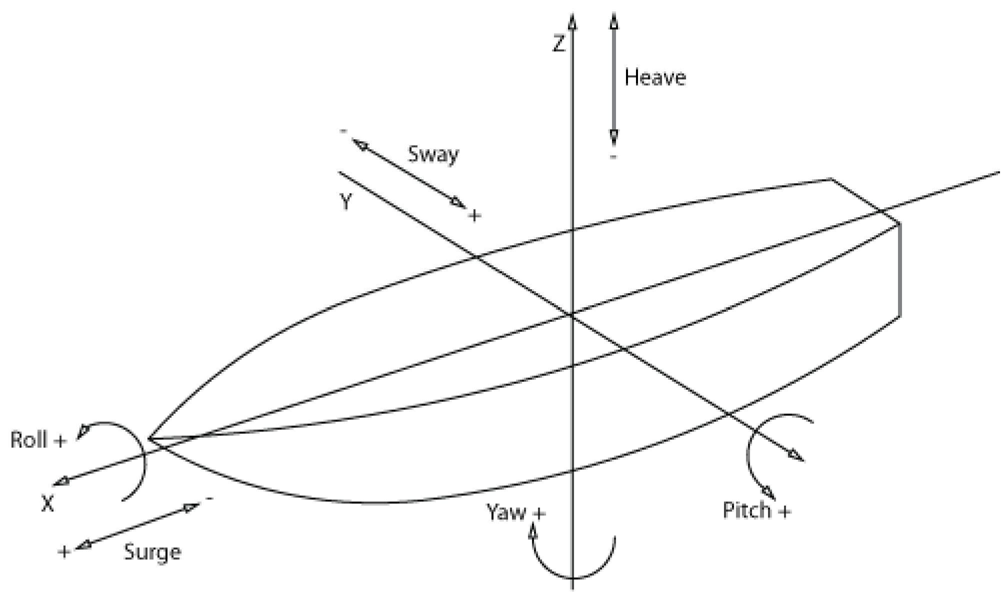

Figure 1. 1 Reaction of floating structure upon load acting on them.

Offshore structures will always have a constant load acting on them such as dynamic load which are wind load and wave load. As for floating wind turbine, additional load need to be considered which is gyro effect of the rotating blades that can affect the stability of the floating wind turbine. Stability of wind turbine can be demonstrated as surge, sway, yaw, roll, pitch and heave such as the figure above.

The correlation of gyro effect of the fan blade towards the stability of floating wind turbine have to be observed so that the stability of the structure can be maintained.

Thus, in order to achieved that, the gyro effect towards the stability of the floating structure must be analyse. The results of the study are based on the simulation created in a software called Star CCM which then will be compared with past research paper which using different kind of approach to study the effect of rotating fan blade toward the stability of the floating wind turbine.

1.2 Problem Statement

Due to rotating motion of the fan blade of the Floating Offshore Wind Turbine will produce additional motion which also will be combined together with environmental load which is wind, wave and current to produce uncertainty on the stability of the structure. The stability of a Floating Offshore Wind Turbine in the sea is commonly described as 6-Degree of Freedom. This degree of freedoms is consisting of 3 translational motion, heave, sway and surge, and 3 rotational motion, roll, pitch and yaw. Hence a study will be conducted to study the reaction of the loads and identifying which is the most affected motion due to the rotating fan blade.

1.3 Objectives

The objectives of the study will be as below:

1. To analyse the stability of Floating Offshore Wind Turbine with rotating blade and identifying the critical motion produce.
2. To compare and confirm the data produce between numerical and experimental can be similar.

1.4 Scope of Study

The study will focus on the study that has been made by Nishimura. He and his team has done the experimental research on the stability of Floating Offshore Wind Turbine. The research was done inside the lab with water tank and motion capture camera to accurately capture the motion of the Floating Offshore Wind Turbine. The outcome of the research is in 6 degrees of freedoms. The conclusion concluded that the most affected motion is yaw motion which is the rotational motion at z axis.

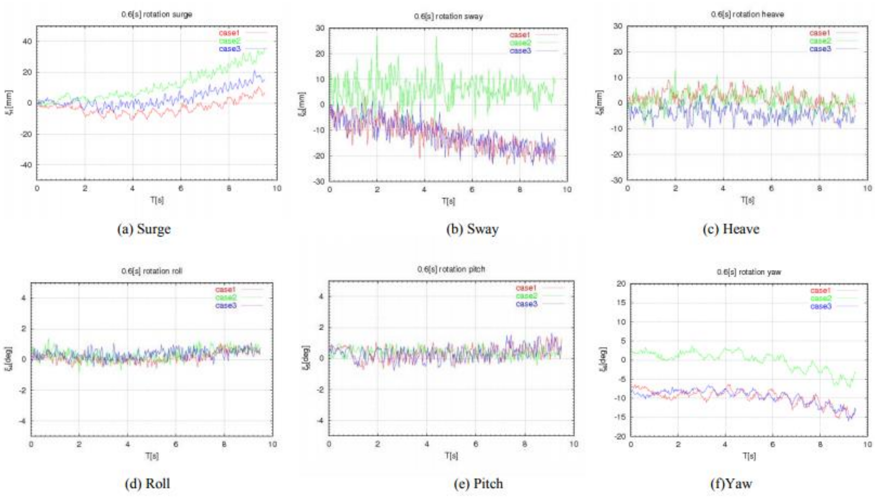

Figure 1. 2 Example of the results outcome

With the result from the experimental research, the objectives of the project which is to compare the results from numerical and experimental results can be achieved. However due to limitations of the capability of the machinery to carry out the simulation on all type of the motion, the study will focus only on the major significant changes occurred during the simulation which was concluded by Nishimura research, Yaw motion.

1.5 Relevancy and Feasibility

The study relevancy can relate on how effective the outcome of the project is expected to produce with respect to the objective of study. Studying this effect is part of the Civil Engineering study, moreover for individua who’s taking offshore as their major which is more focus on the fixed and floating structure offshore. Having Star CCM+, a new Computational Fluid Dynamic software that underutilise in simulating a Floating Offshore Wind Turbine, it is consider fitting to be carried as a study in order to study the stability of Floating Offshore Wind Turbine by using Star CCM+. Own research, discussion with supervisor, software, Gantt chart and key milestone are the aids for this study that is deemed to be feasible to be conducted with a period of 28 weeks.

CHAPTER 2

LITERATURE REVIEW

2.1 Dynamic Motion in Floating Wind Turbine.

The stream field around a wind turbine is regularly demonstrated as a relentless, uniform, hub wind. As a general rule, the stream around a turbine edge is a more intricate process that incorporates misalignments, wind shear, turbulence and dynamic winds. For a drifting seaward flat hub wind turbine (HAWT), this handle turns out to be more mind boggling than for a coastal or settled seaward framework (Thanh-Toan et. al.,2015).

Due to the movement of drifting wind turbine, which incorporates three translational parts (overwhelming in the vertical, influence in the sidelong and surge in the pivotal) and rotational segments (yaw about the vertical hub, pitch about the sidelong, and move about the pivotal), the extra impact of the commitment of a wind is represented in the turbine framework. Physically, the flow-field around a rotating wind turbine blade is inherently complex because of the existence of wind shear, turbulence, gust, and yaw motion of the nacelle. For a floating offshore, horizontal axis wind turbine (HAWT), flow characteristics become more complex than those of a fixed offshore wind turbine. Because of the motion of floating platform, which includes three translational components (heave in the vertical, sway in the lateral, and surge in the axial) and three rotational components (yaw about the vertical axis, pitch about the lateral, and roll about the axial) motion, the additional effect of the wind contribution which is basically transmitted to the rotor due to the platform motion needs to be considered. In those motions, platform pitch and yaw degrees of freedoms significantly lead to the unsteady aerodynamic effects on the rotating blades combining the effect of wind shear, gradient across the rotor disk, dynamic stall, rotor blade–wake interaction, and skewed flow (Thanh-Toan et. al.,2015).

Generally, about the dynamic motion of the floating structure, the motion by the ocean waves becomes the large problem. It is, however, the important problem that not only the influence of the ocean waves but also the influence of the gyro moment by the rotation of the windmill should examine in the floating-type wind-generated electricity facility (M. Murai et. al.,2010).

Because the tower of the windmill is fixed in the case of grounding-type wind-generated electricity facility, the change of the rotor surface of revolution of the windmill is extremely small. In contrast, in the case of a floating type, the whole floating structure is upset by ocean waves. Therefore, rotor surfaces of revolution of the windmills always vibrate. When a rigid body turning like a top and a gyro caught the force to change a surface of revolution, it is known by the rigid body that stability force occurs. In the floating structure-type wind generated electricity facility, we can imagine that the influence appears easily. When the influence on oscillation of the floating structure by the rotation of the windmill is not so big, it is reported by the existing research, but there are extremely few examples which really confirmed those influence experimentally. In this report, we experiment on the water tank using the model of the SPAR type offshore floating wind-generated electricity facility and examine the influence that the rotation of the windmill in the waves gives to motion of the floating structure (M. Murai et. al.,2010).

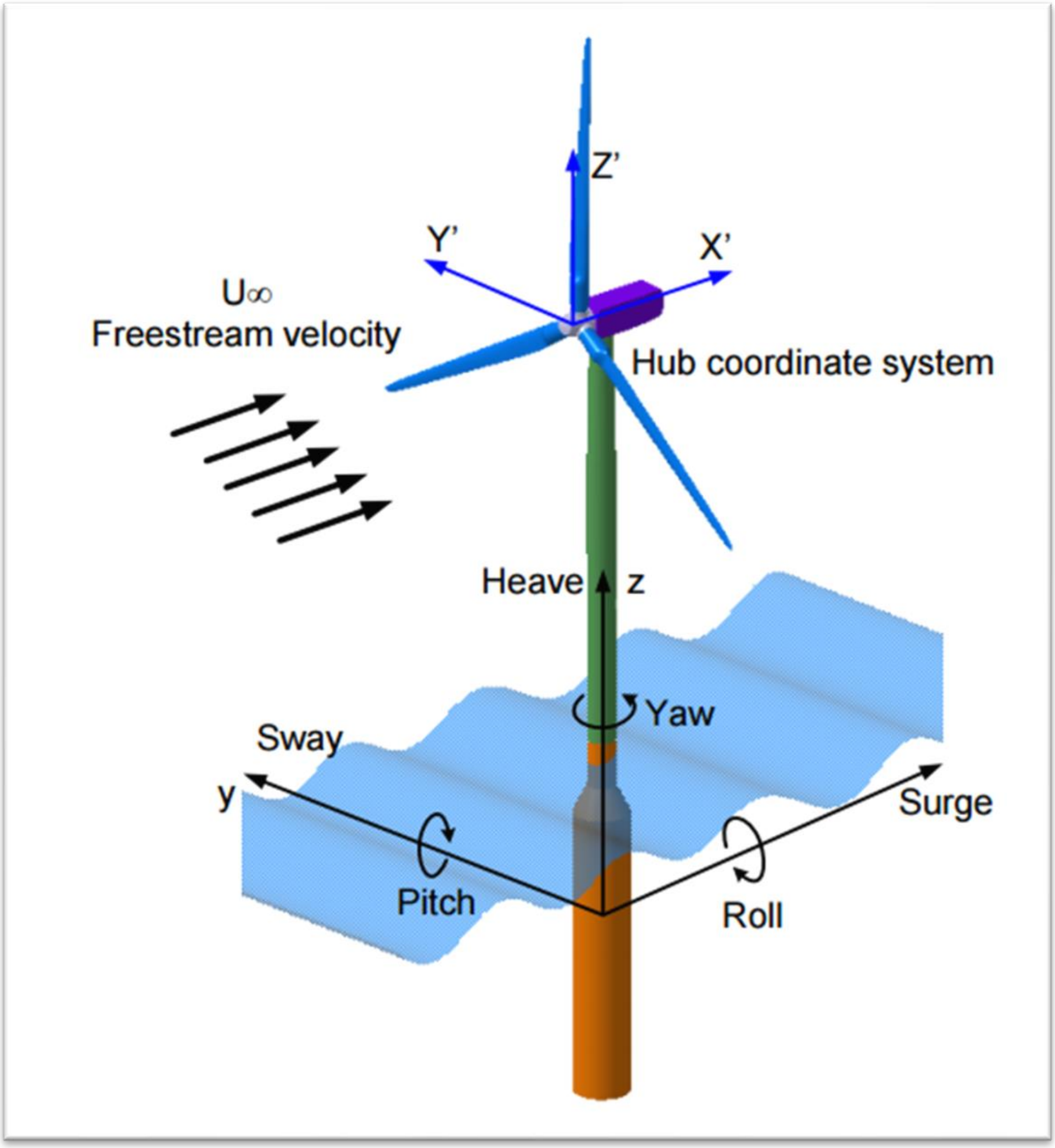

Figure 2. 1 Resultant motion produce in FOWT

2.2 Floating wind turbine.

The base of the tower is correspondent with the highest point of stage and is situated at a rise of 10 m over the still water level (SWL). The highest point of the tower is correspondent with the yaw bearing and is situated at a height of 87.6 m over the SWL. This tower-best height—and the comparing 90 m rise of the centre point over the SWL—is reliable with the land-based form of the NREL 5-MW standard wind turbine. These properties are all in respect to the displaced position of the stage(J.Jonkman. 2010).

The appropriated properties of the tower for the NREL 5-MW pattern twist turbine on the OC3-Hywind fight float are established on the base distance across of 6.5 m, which coordinates the top width of the stage, and the tower base thickness (0.027 m), beat breadth (3.87 m) and thickness (0.019 m), and powerful mechanical steel properties of the tower utilized as a part of the DOWEC think study. The Young's modulus was taken to be 210 GPa, the shear modulus was taken to be 80.8 GPa, and the successful thickness of the steel was taken to be 8,500 kg/m3. The thickness of 8,500 kg/m3 was intended to be an expansion over steel's common estimation of 7,850 kg/m3 to represent paint, jolts, welds, and ribs that are excluded in the tower thickness information. The span and thickness of the tower are thought to be straight decreased from the tower base to tower best. Table 2-1 gives the subsequent circulated tower properties (J.Jonkman, 2010).

The subsequent general (coordinated) tower mass is 249,718 kg and is focused (i.e. the focal point of mass [CM] of the tower, is situated) at 43.4 m along the tower centreline over the SWL. This is gotten from the general tower length of 77.6 m (J.Jonkman, 2010).

Table 2. 1 Characteristic of the structure

Elevation to Tower Base (Platform Top) Above SWL	10 m
Elevation to Tower Top (Yaw Bearing) Above SWL	87.6 m
Overall (Integrated) Tower Mass	249,718 kg
CM Location of Tower Above SWL Along Tower Centerline	43.4 m
Tower Structural-Damping Ratio (All Modes)	1%

The tower is cantilevered at a rise of 10 m over the SWL to the highest point of the gliding stage, which—for the reasons for examination—is thought to be an inflexible body. The draft of the stage is 120 m. Between the top and base of the stage, the OC3-Hywind fight float comprises of two tube shaped districts associated by a directly decreased cone shaped locale. The chamber distance across of 6.5 m over the decrease is thinner than the barrel width of 9.4 m underneath the decrease to lessen hydrodynamic loads close to the free surface (J.Jonkman, 2010).

The roll and pitch latencies of the drifting stage about its CM are 4,229,230,000 kg•m2 and the yaw idleness of the gliding stage about its centreline is 164,230,000 kg•m2. These idleness's were computed utilizing a mass dissemination fitting to the skimming stage. The dormancies of the full OC3-Hywind framework are higher than those of Statoil's Hywind framework in light of the fact that the NREL seaward 5-MW benchmark wind turbine is heavier than the turbine in Statoil's Hywind framework (J.Jonkman, 2010).

Table 2. 2 Characteristic of the structure

Depth to Platform Base Below SWL (Total Draft)	120 m
Elevation to Platform Top (Tower Base) Above SWL	10 m
Depth to Top of Taper Below SWL	4 m
Depth to Bottom of Taper Below SWL	12 m
Platform Diameter Above Taper	6.5 m
Platform Diameter Below Taper	9.4 m
Platform Mass, Including Ballast	7,466,330 kg
CM Location Below SWL Along Platform Centerline	89.9155 m
Platform Roll Inertia about CM	4,229,230,000 kg•m^2
Platform Pitch Inertia about CM	4,229,230,000 kg•m^2
Platform Yaw Inertia about Platform Centerline	164,230,000 kg•m^2

2.3 Star CCM+

STAR-CCM+ is a CFD and Continuum Mechanics program made by CD-adapco. Computer aided design also, work geometry can be foreign made or made in the program to speak to the spaces that can be tackled for liquid stream, warm exchange, and stress. Due to the capacity to import three-dimensional models, STAR-CCM+ loans itself well to re-enacting complex geometries, and its customer server engineering takes into consideration multi-client joint effort. This part talks about the customer server design of STAR-CCM+ and contains an assessment of its shared capacities (Kasey Webster, 2015).

Joint effort is empowered in STAR-CCM+ by its customer server engineering. At the point when a re-enactment is made or opened through the STAR-CCM+ workspace a customer and server are made that compare to that specific reproduction. In the thin customer - thick server design of STAR-CCM+ the customer is the place the client can set-up the recreation through the graphical client interface (GUI) or a group script, and the server is the place summons and operations are executed and afterward sent back to the customer to be shown. The fundamental advantage of this sort of design is that the information on each of the customers is stayed up with the latest. Since most of the work is done on the server, elite is not required for the customers, and the speed of the reproduction set-up is definitely not controlled by one slower customer (Kasey Webster, 2015).

Figure 2. 2 Star CCM+

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The purpose of the study is to study the effect of dynamic loads toward the stability of floating offshore wind turbine. In order to formulate such results, several steps will be implemented as in the outline below:

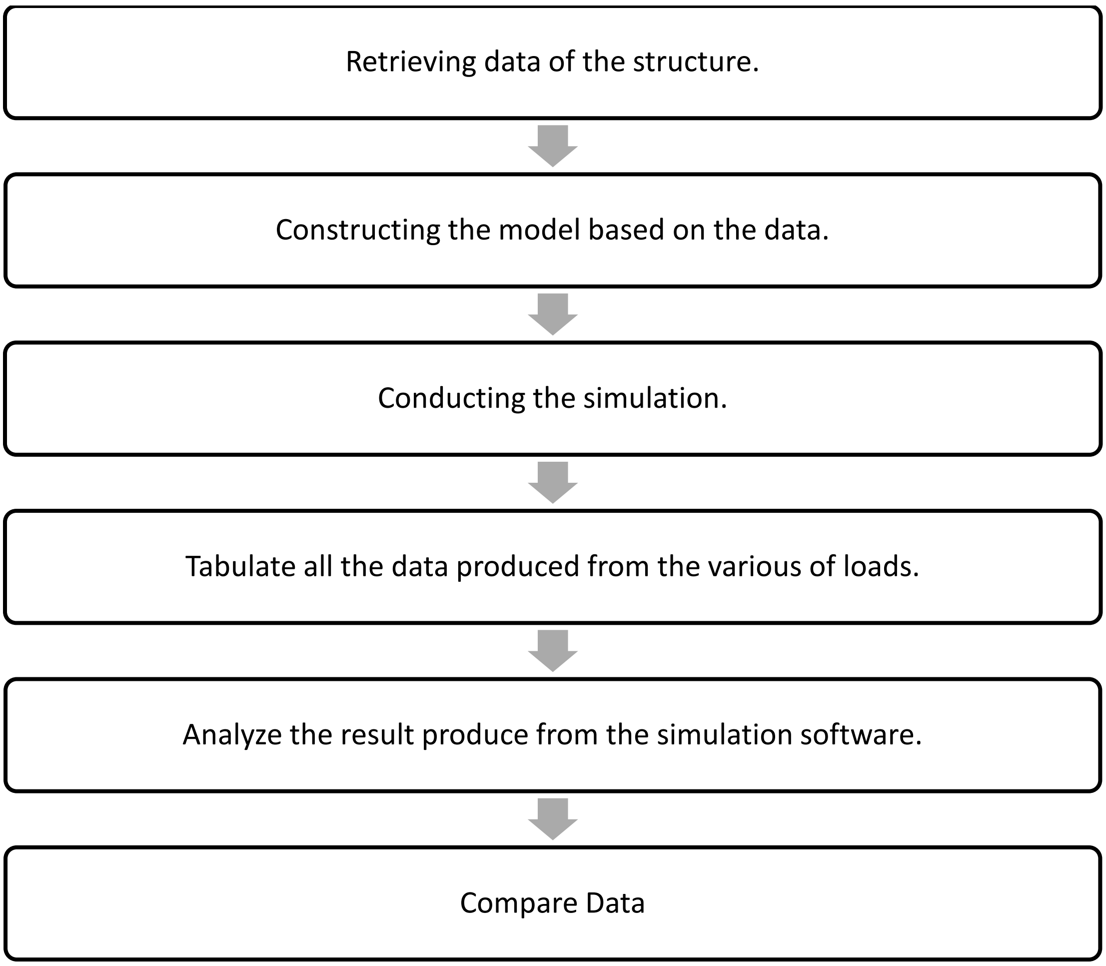

Figure 3. 1 Methodology adopted in the study

3.1.1 Retrieving Data

The data retrieved is the dimension of the experiment and actual dimension of the structure that was being used by the previous researcher. Besides that, the experiment criteria also obtained. The data obtained will be used in constructing the model and the environment inside of the software:

Table 3. 1 The characteristic of the structure

Depth to Platform Base Below SWL (Total Draft)	120 m
Elevation to Platform Top (Tower Base) Above SWL	10 m
Depth to Top of Taper Below SWL	4 m
Depth to Bottom of Taper Below SWL	12 m
Platform Diameter Above Taper	6.5 m
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Elevation to Tower Base (Platform Top) Above SWL	10 m
Elevation to Tower Top (Yaw Bearing) Above SWL	87.6 m
Overall (Integrated) Tower Mass	249,718 kg
CM Location of Tower Above SWL Along Tower Centerline	43.4 m
Tower Structural-Damping Ratio (All Modes)	1%

3.1.2 Creating the Structure and the Environment

From the data acquired from the previous research has been made, an exact model also is being used so that the result produce will able to compare with the result produce in the lab and the one produce by using the software Star CCM+. In order to build up the model, a 3-D Cad interface is provided in the software itself. With the interface provided, a 3-D model of any structure is possible to be made. In order for the structure to be simulated, the model must be build up in solid body so that the physics of the software able to generate the simulation.

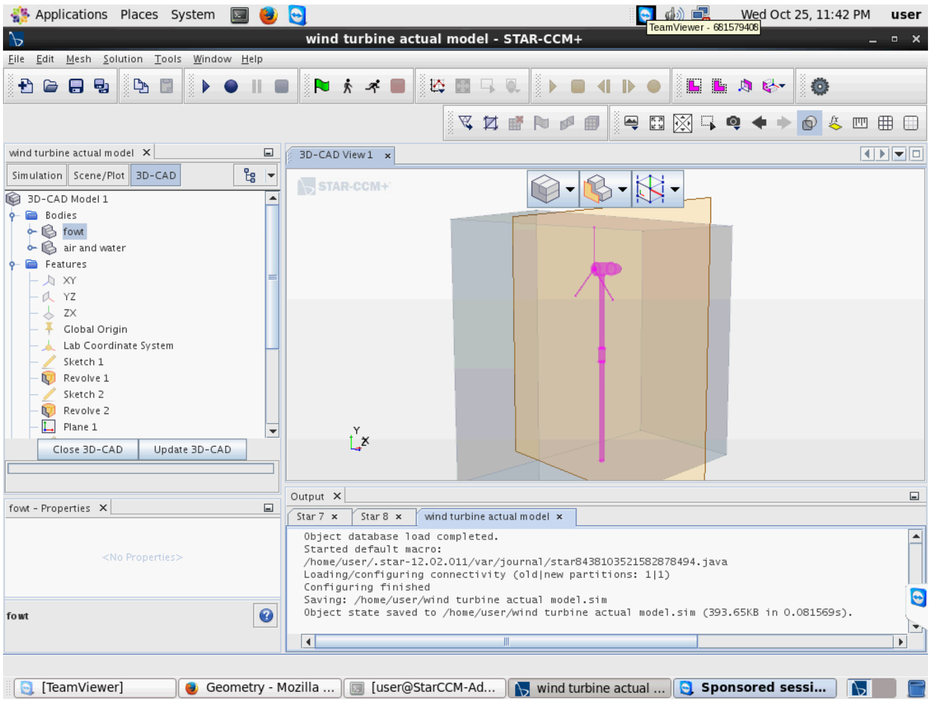

Table 3. 2 3-D model of the structure with its environment

3.1.3 Meshing

In order the structure to be simulate smoothly, a meshing process is needed. Meshing process can determine the smooth outcome of the result. The meshing is based on the number of cells. The higher the number of the cells the smoother the simulation but taking a longer time to finish due to high accuracy of the mesh. In general, for this software it has two meshing option which both needed to be done. The first meshing is surface meshing where the software will create meshing cell on the target object or structure which is inside the environment domain. The second meshing will be volume meshing which will mesh the environment domain. Both of these can be adjusted manually according on how many cells the user wants for their simulation.

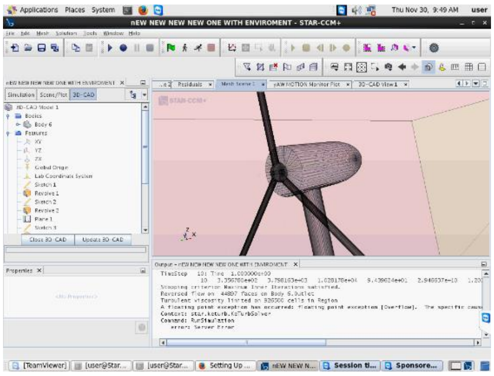

Figure 3. 2 The surface meshing on the FOWT

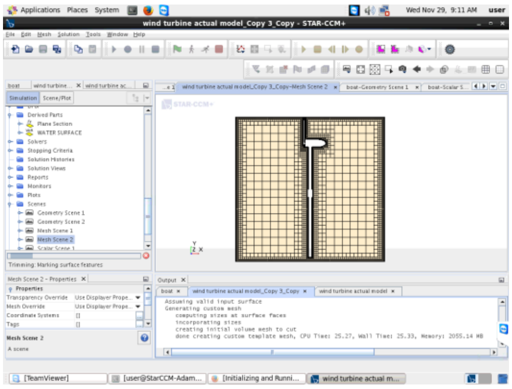

Figure 3. 3 The volume meshing of the environment

3.1.4 Setting up the physics

Soon after finish with the meshing of the environment and the structure, the user has to define the environment physics. In Star CCM+, it is called as Volume of Fluid, it's a built in the software itself. VOF will able the environment to generate type of liquid region in the software. The wave generated and the current of the fluid can totally be adjusted to the user preferences. Besides that, to be able to study the motion of the structure toward the wave generated, a 6-DOF capabilities built in the software will be used. With this, a motion result from the wave can be generated and the transitional and rotational will able to produce the graph so that can be compared later during the analysing phase.

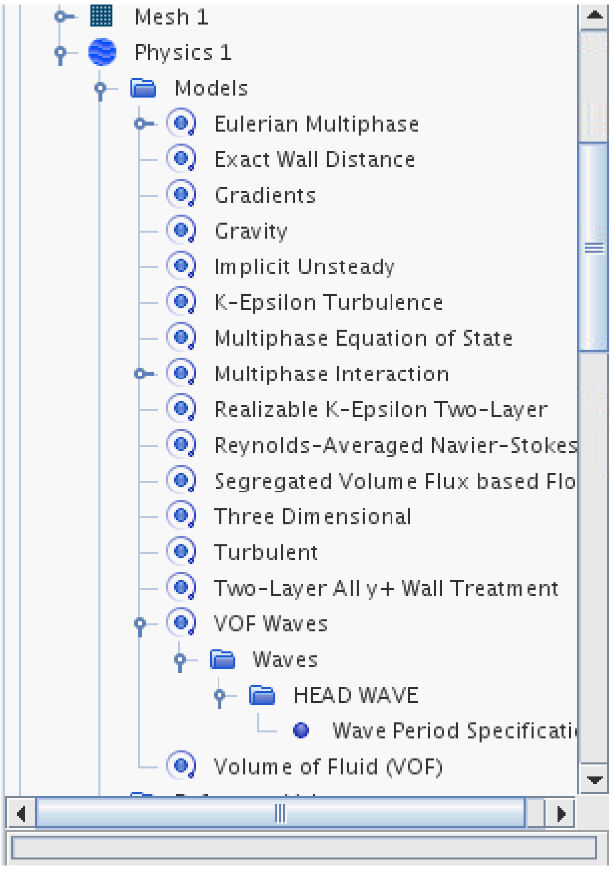

Figure 3. 4 The physics that being set up inside the simulation

3.1.5 Simulation

Once the model is meshed and the environment have been set, the simulation can be started. The simulation is customable according to the user. The determination factors are Implicit Unsteady, Maximum Inner Iterations and Maximum Physical Times. Below is an example of a running simulation.

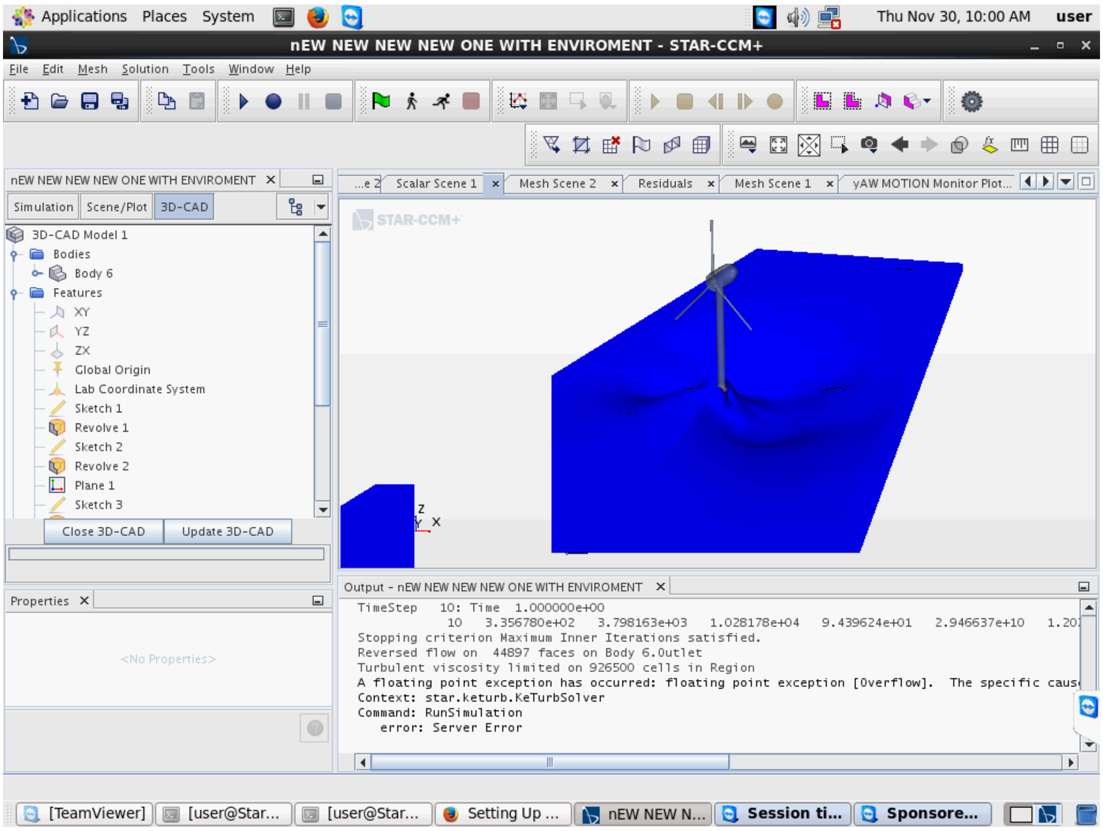

Figure 3. 5 A running simulation

3.1.6 Tabulate Data, Analyse and Compare Data

As soon as the simulation finished, a number of graph can be produce from the simulation process. Then the graph will be compared with the previous research to compare the results of the loads toward the stability of the floating offshore wind turbine.

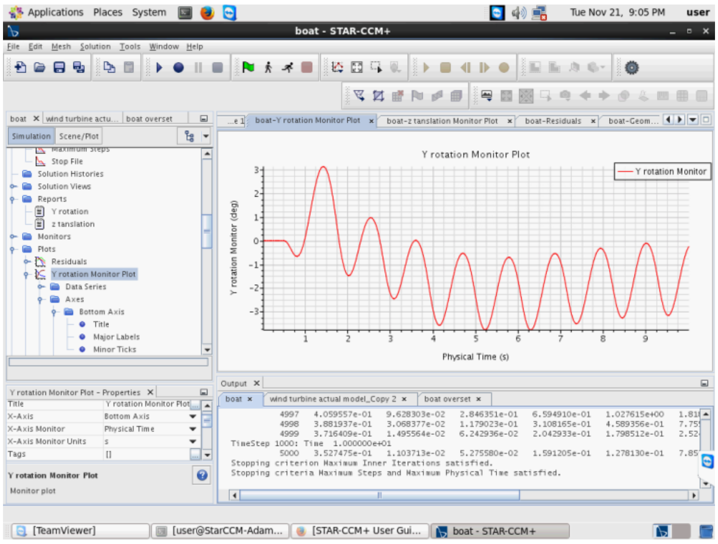

Figure 3. 6 Example of result outcome from Star CCM +

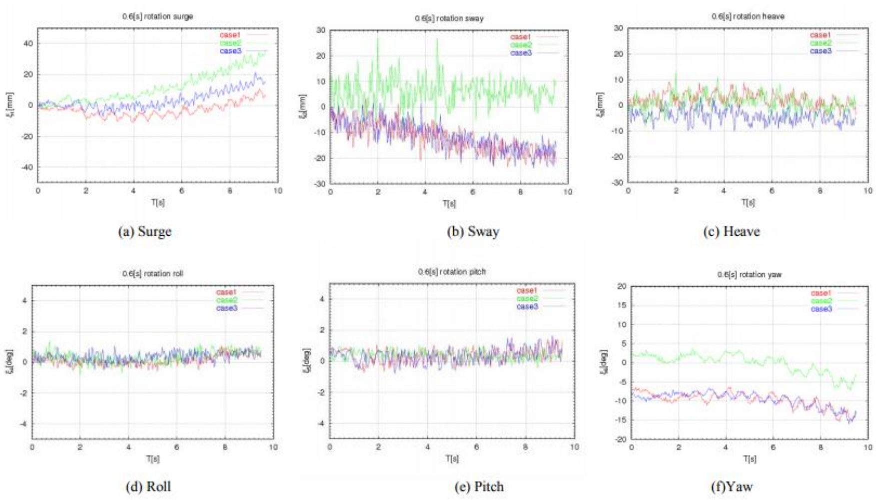

Figure 3. 7 Tabulated data from previous research

3.2 Project Key Milestones for FYP I & II

Table 3. 3 The milestone plans

Details / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	FYP I														
FYP title selected		•													
FYP title approved			•												
Submitted Extended Proposal Draft						•									
Submitted Extended Proposal							•								
Proposal Defence										•					
Submitted Interim Report Draft													•		
Submitted Interim Report														•	
	FYP II														
Submission of Progress Report Draft						•									
Submission of Progress Report							•								
Pre-SEDEX										•					
Submission of Final Report Draft											•				
Submission of Dissertation Draft												•			
Submission of Dissertation												•			
Submission of Technical Paper Draft												•			
Submission of Technical Paper												•			
Viva													•		
Submission of Project Dissertation Draft														•	
Submission of Project Dissertation															•

3.3 Project Timeline (Gantt Chart) for FYP I & II

Table 3. 4 The activities planned in FYP I

Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Preliminary research on possible FYP title														
Selection of title														
Approval of title by Supervisor and Coordinator														
Collect resources for research														
Research for Proposal Draft input														
Discussion with Supervisor														
Submission of Extended Proposal Draft														
Submission of Extended Proposal														
Conduct preliminary data analysis														
Prepare slides for Proposal Defence presentation														
Proposal Defence presentation														
Further research for Interim Report Draft input														
Submission of Interim Report Draft														
Submission of Interim Report														

Table 3. 5 The activities planned in FYP II.

Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Data analysis and calculation	■	■	■	■	■										
Discussion with supervisor	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Submission of Progress Report Draft						■									
Submission of Progress Report							■								
Prepare slides for Pre-SEDEX									■						
Pre-SEDEX										■					
Further analysis and conclusion of study										■	■				
Submission of Final Report Draft											■				
Submission of Dissertation Draft												■			
Submission of Dissertation												■			
Submission of Technical Paper Draft												■			
Submission of Technical Paper												■			
Prepare slides for Viva													■		
Viva													■		
Submission of Project Dissertation Draft														■	
Submission of Project Dissertation															■

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results and discussions.

4.1.1 Difference in graph.

Without Rotating Fan Blade

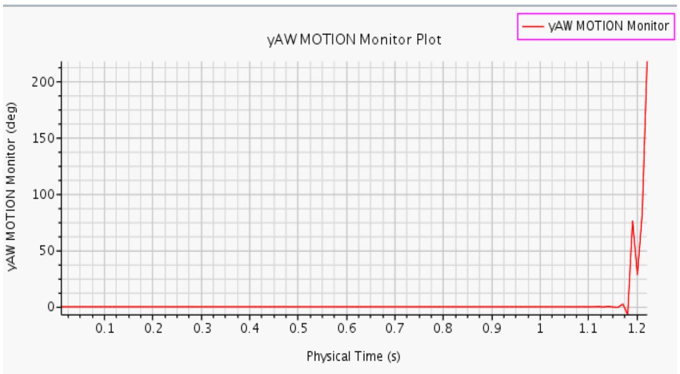

Figure 4. 1 Numerical Yaw Motion with no rotating fan blade

The numerical graph starts to produce after 1 sec, should be after 0.5s. This is because the setting of the simulation, the setting of the simulation to release the body at 0.5 seconds and the ramp time will be ten time of the release time. This to ensure that the waver generated is able to mimic the wave in the ocean before the bode of the structure to be release. And the reason why the graph only produce to 1.2 seconds is because the simulation encountered an error. In the short moment here, we can see that, there is yaw motion and recovery motion, but the result is not as expected because the graph go higher without any recovery force. This should happen as there will be no additional force to help the yaw motion.

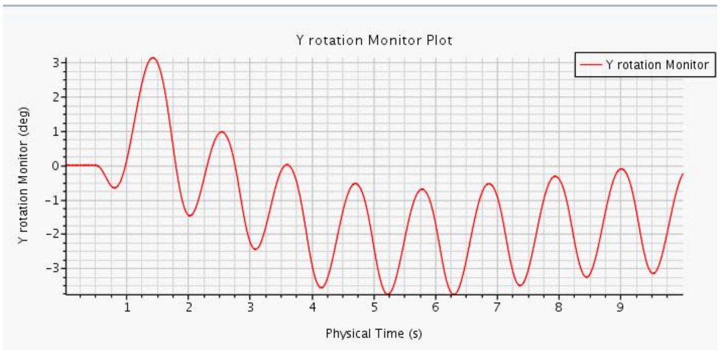

Figure 4. 2 Numerical Expected Yaw Motion with no rotating fan blade

The graph above is the numerical expected result produce from the Star CCM+ software. From the graph produce, the behaviour of the yaw motion produce can be study. The graph shows that the yaw motion without any additional motion produce from rotating fan blade is relatively constant throughout the simulation which is 10 seconds. The constant of the graph can be explained because without rotating blade motion, there will be no additional acted on the yaw motion, with equally balance restoring force will able to counter the yaw motion thus explaining the reason behind the constant graph produce from the software.

With Rotating Fan Blade

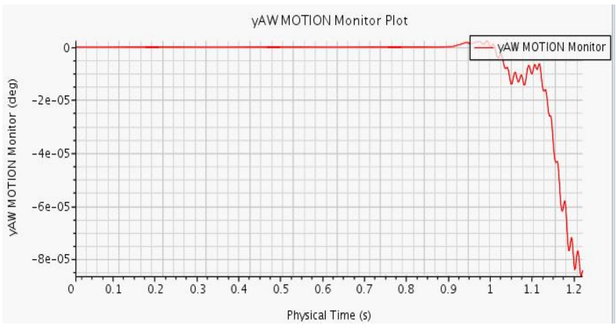

Figure 4. 3 Numerical Yaw Motion with rotating fan blade

From the graph starts to produce after 1 sec, should be after 0.5s. This is because the setting of the simulation, the setting of the simulation to release the body at 0.5 seconds and the ramp time will be ten time of the release time. This to ensure that the waver generated is able to mimic the wave in the ocean before the bode of the structure to be release. And the reason why the graph only produce to 1.2 seconds is because the simulation encountered an error. In the short moment here, we can see that, there is yaw motion and recovery motion, but the result is not as expected because the graph go higher without any recovery force. This should happen as there will be no additional force to help the yaw motion.

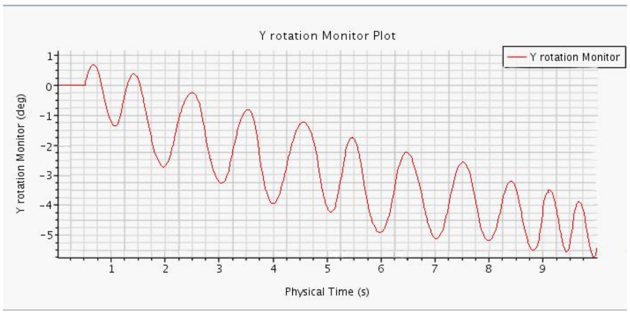

Figure 4. 4 Numerical Expected Yaw Motion with rotating fan blade

As for the graph having a rotating fan blade, the graph behaviour is very different. As the graph compare side by side, there is more drop in the graph with rotating fan blade. The different in behaviour between these two graphs is because the additional motion produce due to the fan blade motion. This is because, as the fan blade move in one direction, the motion produce will be more significant in one direction thus making the motion induced is much higher compared to the restoring force. With the additional load combined together is higher than the restoring force producing the drop generated in the graph. These explaining the graph behaviour that is going deeper to the Yaw motion is because the structure has higher yaw motion compared to the restoring force to counter the force to stabilise the structure.

4.1.2 Numerical and Experimental graph behaviour.

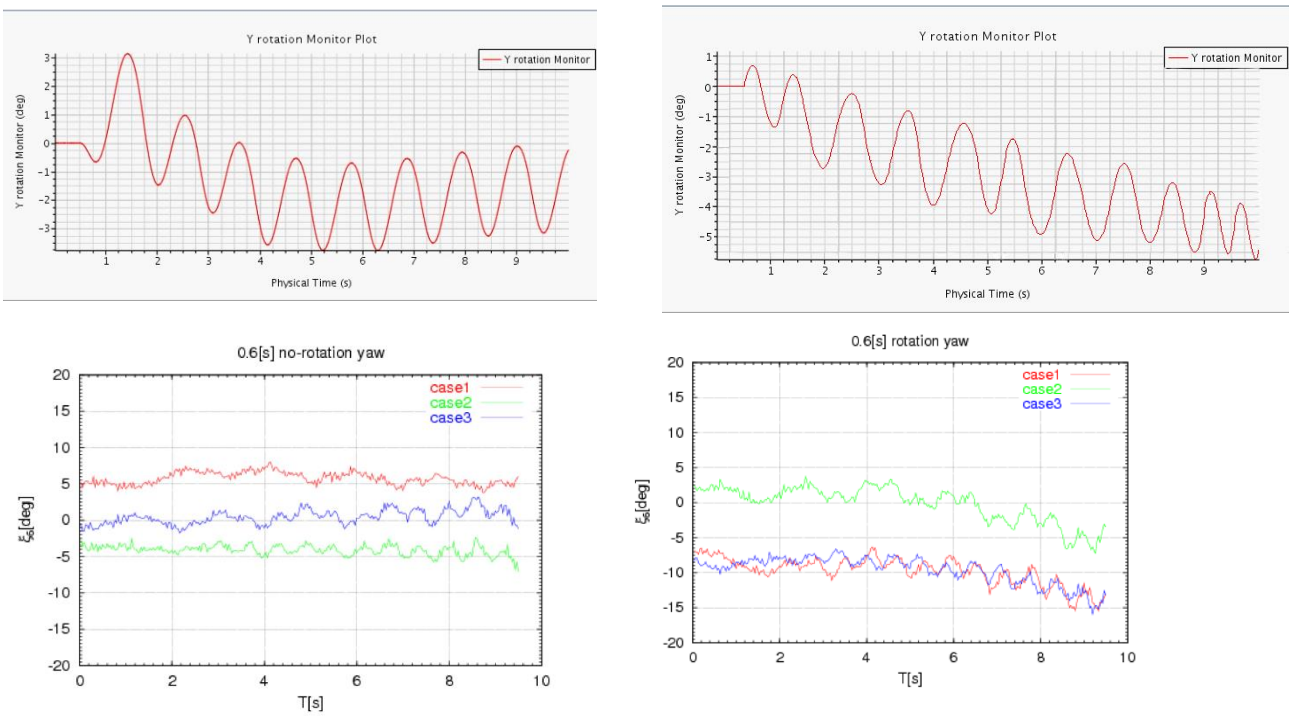

Figure 4. 5 Yaw Motion without and with rotating fan blade

From the figure above is the graphs of yaw motion between numerical results with the experimental results from Mr Nishimura. The graph behaviour for both of the results produce the identical behaviour in both with and without rotating fan blade. Without rotating blade, the graph for both project shows a steady constant graph. As for the graph with the rotating blade also produce same kind of behaviour. Thus, it is safe to say that the numerical and experimental results is identical.

CHAPTER 5

CONCLUSION

5.1 Conclusion

From the results obtained, it is understandable that stability of Floating Offshore Wind Turbine is noticeable affected by the gyro motion of the fan blade at the rotational plane pitch, yaw and roll. Responsive Amplitude Operator of each pitch, yaw and roll can be obtained and analyse with the raw data produced by the software Star CCM+. It is important to adequately understand on how the structure will react with the loadings acting on it during the design phase. The objectives of the project is achievable since the from the result obtained, from the results that movement of fan blade will produce additional motion which can be call as gyro motion. The motion produces due to that amplify the yaw motion of the structures and the motion has become greater than the restoring force thus generate a significant movement in yaw motion. Besides that, the numerical results behaviours are similar to the past experimental behaviours which is mean that the software Star CCM+ is capable to study such topics.

5.2 Recommendations

1. Full case study can be carried out to study all the 6 degrees of freedoms for floating structure.
2. Floating offshore wind turbine can be a very important asset due to the limitation landfills. With this project, can provide a better insight in stability of floating offshore structure. If this is done within Malaysia sea water region, can be give more insight on sea behaviour of this region on the floating offshore structure.

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