Power Systems Analysis in an Induction Type Wind Turbine

PROJECT PLAN

42

Ron Zickefoose

James McCalley

Nick David

Ben Zickefosse – Team Lead

Melissa Flood – Power Engineer/Chief Engineer

Tate Stottmann Power Engineer/Test Engineer

Matt Miner – Power and Controls Engineer/Meeting Scribe

David Clark – Controls and Embedded Engineer/Report Manager

bjz@iastate.edu

http://sdmay18-42.sd.ece.iastate.edu/

Revised: 10/26/2017

Table of Contents

List of Figures

Figure 1- The inside of the induction motor with the gearbox

Figure 2- The placement of the wind turbine and the connecting wires to the electric grid.

List of Definition

Induction Motor- An EC electric motor which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. [1]

Islanding-A condition in which a distributed generator continues to power a location even though the electrical grid power is no longer present. [2]

NOTE: This template is a work in progress. When in doubt, please consult the project plan assignment document and associated grading rubric.

REC-Rural Electrical Company. This is the electric utility company that our team is working with. It operates the utilities where the wind turbine will be built.

1 Introductory Material

1.1 ACKNOWLEDGEMENT

A lot of the design came from Bob Zickefoose, a MSME teacher in Virginia who also has a similar 'sister' tower on his property in West Virginia. Much of the structure came from Ron Zickefoose, the client, and from Global Machine Company in Hampton, Iowa. That being said there is still no shortage of work left for our team to do.

1.2 PROBLEM STATEMENT

The client Ron Zickefoose designed and is building a wind turbine on his property to provide cheap and clean energy for his power consumption. In order to interconnect to the power grid and supply a small amount of power to the induction motor to start rotation, the power utility requires proof that the generator will not cause any islanding on the power grid. Which would cause voltage to flow back to the grid, causing a safety hazard for anyone working assuming that there is no voltage if the rest of the power grid is turned off. The wind turbine should be able to supply enough power for our client's needs, and enough to sell back to the utility.

Creating a model criteria for interconnecting on the power grid for a functional turbine. To supply a fully functional wind turbine adjusting the tail fin of the turbine and fully building the turbine is in order. Designing the interconnecting criteria will prove that the wind turbine will not cause any islanding issues with the utility tests will be done on the induction motor used. To run tests on the induction generator, a second motor can be hooked up to for maximum output, and what power is needed to start the induction generator. Showing the initial power is needed and a constant supply is there while outputting power will prove that voltage can't be supplied by the motor without the reactive power from the grid. Additionally there will be a detailed research, analysis, description of the capabilities, limitations of the induction motor. This research will allow for the wind turbine to be hooked up to the grid and supply power and income to our client.

1.3 OPERATING ENVIRONMENT

The wind turbine will be open to the elements. The turbine stands at 110 ft. tall and will be subjected to any wind, rain, hail, snow and ice. During lightning storms lightning will have a large percentage of hitting the tower. Since most of the turbine is made from metal the temperature outside will affect the structure and will be subjected to expansion and contraction.

1.4 INTENDED USERS AND INTENDED USES

The intended users of the wind turbine is the owner of the property that it stands on. In this case our client Ron Zickefoose is the user. The nearby utility will also be an intended user of the wind turbine as they will get electrical energy from the turbine.

The property owner will get the most use out of the turbine. They will be able to offset how much money is spend on their electricity bill from their own consumption. In addition to that any extra electricity produced will be sold to the utility. Once the utility gets electricity they will be able to generate less power and use the wind turbine to sell electricity to their customers.

1.5 ASSUMPTIONS AND LIMITATIONS

Assumptions

The air density is a constant throughout the year

That the two legs of single phase voltage with an evenly split phase shift

240 Volts phase to phase

120 Volts phase to ground

Limitations

The induction motor will turn into a generator after 1800 RPM

The system must operate at 230 volts and 60 Hertz

The current will run at 20.6 Amps

1.6 EXPECTED END PRODUCT AND OTHER DELIVERABLES

Blueprints of a one line, three line and control wiring. If possible the mechanical prints and a sitemap will be an addition. These blueprints will show exactly how the wind turbine is set up and how it functions. This will be delivered by the end of the project on April 30th 2018.

A GUI showing different data points of the wind turbine. This GUI will show the current wind speed and direction, and the output power of the wind turbine. The is useful in collecting data on the wind turbine and how efficient it operates. This will be delivered by the end of the project on April 30th 2018.

A wind turbine will be operating by the end of the project. This is the main focus of the project and will stand at 110ft with a 4kW induction type motor. This will be delivered by the first part of second semester February 12th, 2018.

2 Proposed Approach and Statement of Work

2.1 FUNCTIONAL REQUIREMENTS

Wind turbine

- Structure
  - 110 ft. tall
  - Triangle base (three legs)
  - Induction type wind generator
  - 4kW expected output
  - 3 - 10 ft. blades

2.2 CONSTRAINTS CONSIDERATIONS

IEEE Standards-IEEE standards are used by the utility as what is a valid electrical component and how it should run. There are many tests in IEEE standards that state exactly how to run a certain test and what should be looked at.

Iowa Law-make sure that the electrical grid is effective and safe

National Electric Code (NEC)- This code goes into the standards of everything that is running power on our wind turbine. It states what type of grounding wire is needed for the motor we have and using this code makes sure that everything is done properly. Insuring that our project will both work, and not potentially hurt anyone who uses the turbine.

Occupational Safety and Health Administration (OSHA)-These rules will make sure that when the turbine is being build, it's being done in a safe manner and no one will get hurt when this happens. This is very important for our group because we are building a larger structure and we don't want anyone to be injured while working on our project.

2.3 TECHNOLOGY CONSIDERATIONS

There are many strengths in the available technology for wind turbines.

One feature of induction motors used as generators is that a constant power is needed to output real power. This is useful due to the fact that if the grid goes off then power can't backflow to the grid causing islanding. No additional circuitry is needed to be build or the cost of extra components like a voltage controller. On the other hand you will always be spending some money in order to make money to sell back to the grid. This also means that if there is a power outage the turbine will not be able to support the property independently if there is a power outage, or if the utility decides not to hook up reactive power, the turbine won't be able to run. Another way to go about this is to use a synchronous motor instead that can run without reactive power and only needs wind to generate electricity. Unfortunately synchronous motors are more expensive than induction motors, especially when considering the extra circuitry required that is needed to be installed with it.

Induction motors on their own, there are many different ratings that will produce different max power outputs. The more power it can output the more expensive and the larger the motor gets. A balance needs to be found between being able to produce enough to produce electricity for the property while still being cost effective. The size consideration is also important since the motor will rest on top of the tower and there needs to be a way to lift and support the motor onto the 100ft tower.

2.4 SAFETY CONSIDERATIONS

There could be a tradeoff in how we handle the communications that the client will have with the tower itself. On the one hand we could use 'the internet of things' and 'talk' to the tower via Wi-Fi that however could be problematic since the internet at the tower site gets pretty spotty during inclement weather. On the other hand we could bury a phone (Cat-5) cable going from the tower to the house for the client to be able to interact with the GUI. This will mean digging a trench and getting a cable rated for direct burial and then making up the correct piping to sheath it in at either end of the buried run.

2.5 PREVIOUS WORK AND LITERATURE

Wind turbines of various size and quantity have been connected to the grid throughout the world. With the United States having 65.9 gigawatts [3] of power coming from wind and around 2 gigawatts from Iowa alone [4]. Previous construction of wind turbines help our group with researching expected power output from turbines and have an idea of concerns that can happen with a running turbine. For example knowing to have a cutoff speed for the turbine so the blades don't spin off, or having a lightning rod attached to the turbine.

Our group is using a squirrel cage induction motor for the turbine. These types of motors were patented by Nikola Tesla in 1888 [5] and have been used as an induction generators in various times throughout history. This proves useful to find equations that will be needed when running tests on our induction motor. It also lets us know that an induction generator won't run without a constant source of reactive power, which is useful in verifying interconnection standards for the power grid.

One con for using an induction generator for a wind turbine is the fact that it isn't as commonly used as a synchronous generator for wind turbines. This is an issue due to the fact of getting more pushback from the utilities from interconnection on them not dealing with this type of wind turbine.

2.6 POSSIBLE RISKS AND RISK MANAGEMENT

The test concluded that the generator does not work for the guild lines for connection to the grid. This is a small risk because design is based on a sister wind turbine.

Another risk our group has is that the induction generator we have is able to output power without having a reactive power supplied to this. While incredible unlikely due to the nature of an induction generator, it is possible when the right conditions are applied at just the right time. If our induction generator is found to do this during research extra circuitry would have to be added to the system to compensate for the lack of system protection.

2.7 PROJECT PROPOSED MILESTONES AND EVALUATION CRITERIA

Table 1- Gantt chart

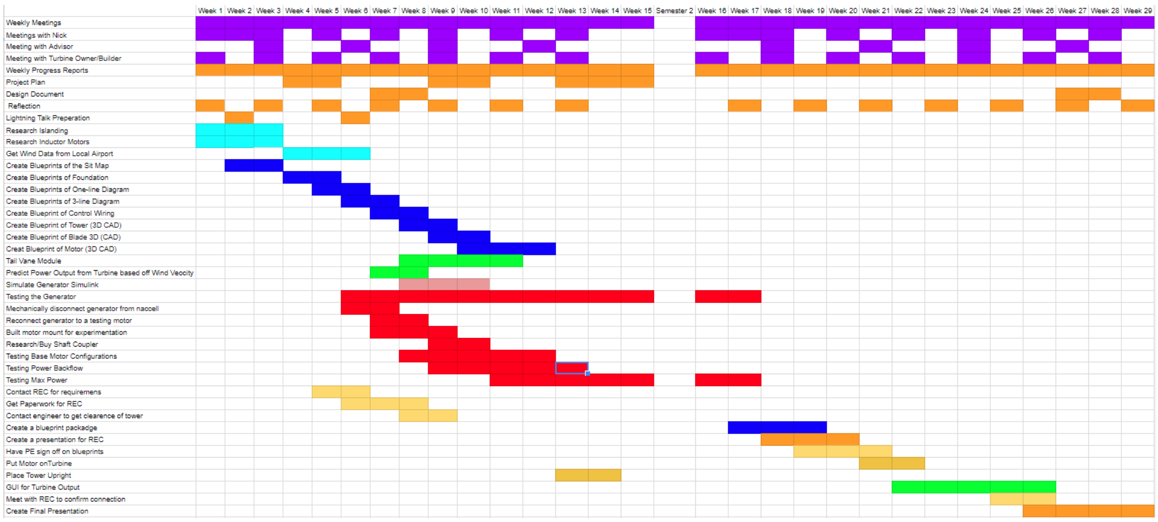


Table 2-Color code for the Gantt chart in Table 1

Meetings	
Documentation	
Reseach	
Other	
Testing Generator	
Simulating Generator	
REC misolaines	
Uprighting the Turbine	
blueprints	

Large milestones for our project include:

- Making all the blueprint
  - Ideally this will be done near the end of the first semester. This task is very likely to take longer due to the fact that no one on our team has experience with CAD and there is a learning curve to pass. And due to our lack of experience it is hard to estimate accurately how long this task will take. This also needs to be done prior to presenting the REC.
- Finish all tests on the generator
  - The deadline for this is have all of the generator tests we want to have completed by the first few weeks in the second semester. This will hopefully give us time to present to REC
- Presenting to REC
  - Ideally this will be done sometime during midterms in the second semester. This will allow time for us to connect to the grid while still getting all of our testing finished

- Setting up a functional Turbine
  - This will hopefully be done around the same time as presenting to the REC mid second semester. This includes having the tail fin working and standing the turbine upright with all the parts attached.
- Connecting to the Grid.
  - If allowed by the REC, connecting to the grid would be the best milestone for our group. This would prove that our tests on the generator and the presentations including blueprints convinced the REC to allow the turbine to be interconnected.

2.8 PROJECT TRACKING PROCEDURES

Submitting things in Google Drive and filling out a progress report in the excel spreadsheet. Confirming with other members in Face to Face contact.

2.9 OBJECTIVE OF THE TASK

Have a wind turbine that is fully functional and make an interconnection agreement with REC with what is needed to put the wind turbine on the grid.

2.10 TASK APPROACH

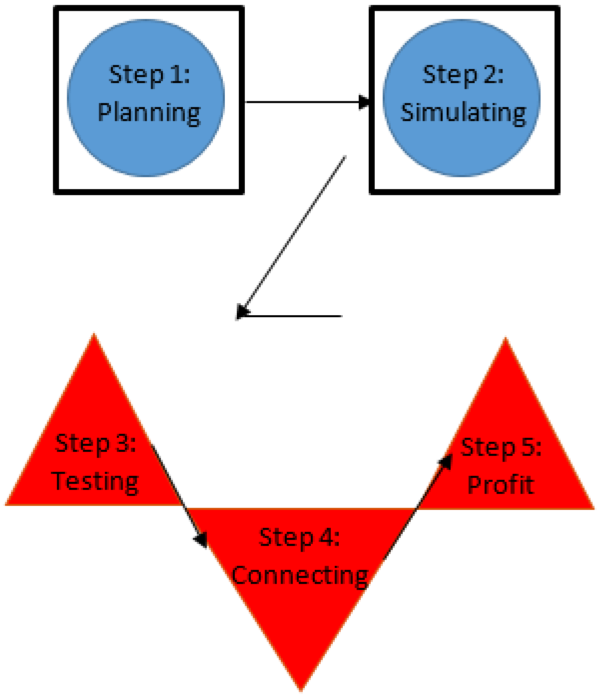
Step 1: Planning – Mapping out what our group is going to do over the next two semesters and what our goals are as a team.

Step 2: Simulating – Working on a computer program to see what the output of our motor should look like in Simulink.

Step 3: Testing – Working on the motor and confirming the data gathered in step 2 to verify the induction motor is working properly.

Step 4: Connecting – Working with the REC to set the wind turbine onto the grid and make sure that the turbine doesn't island

Step 5: Profit – Once connected to the grid power to the house will be provided by themselves and can also sell extra energy back to the REC. How-To's of the design can be sold to other homeowners to make their own wind turbines.



2.11 EXPECTED RESULTS AND VALIDATION

Our desired outcome is that our team has a fully functionally wind turbine that meets the qualifications for interconnecting on the grid. We will confirm this works by doing an island induction motor test. On possible validation is the utility allowing the wind turbine to go on the grid. We can also verify connecting the wind turbine by comparing graphs from our testing with known graphs that pass the tests we are running and see if our generator is comparable.

3 Estimated Resources and Project Timeline

3.1 PERSONNEL EFFORT REQUIREMENTS

Task	Task Deadline	Work Load (hrs per week)	Task Leader
Weekly Meetings	-	1+	All
Meetings with Nick	-	1	All
Meeting with Advisor	-	1	All
Meeting with Turbine Owner/Builder	-	1	All
Weekly Progress Reports	-	1	All/David
Project Plan	Week 15	4	All
Design Document	Week 29	4	All
Reflection	-	1	All
Lightning Talk Preperation	-	1	All
Research Islanding	Week 3	2	All
Research Inductor Motors	Week 3	2	All
Get Wind Data from Local Airport	Week 6	2	Melissa/Tate
Create Blueprints of the Sit Map	Week 3	3	Ben
Create Blueprints of Foundation	Week 5	3	Ben/David
Create Blueprints of One-line Diagram	Week 6	4	Ben/David
Create Blueprints of 3-line Diagram	Week 7	3	Ben/David
Create Blueprint of Control Wiring	Week 8	3	Ben/David
Create Blueprint of Tower (3D CAD)	Week 9	4	Melissa/David
Create Blueprint of Blade 3D (CAD)	Week 10	4	Melissa/David
Creat Blueprint of Motor (3D CAD)	Week 12	4	Ben/David
Tail Vane Module	Week 11	5	Tate/Matt
Predict Power Output from Turbine based off Wind Veocity	Week 8	2	Melissa
Simulate Generator Simulink	Week 10	4	Melissa/Matt
Testing the Generator	Week 17	5	David/Ben
Mechanically disconnect generator from naccell	Week 7	3	Ben
Reconnect generator to a testing motor	Week 8	3	Ben/David
Built motor mount	Week 9	4	David
Research/Buy Shaft Coupler	Week 10	2	Matt/Ben
Testing Base Motor Configurations	Week 12	5	David/Ben
Testing Power Backflow	Week 13	5	Tate/Matt
Testing Max Power	Week 17	5	David/Ben
Contact REC for requiremens	Week 6	1	Ben
Get Paperwork for REC	Week 8	1	All
Contact engineer to get clearence of tower	Week 10	2	Ben
Have PE sign off on blueprints	Week 18	2	All
Put Motor onTurbine	Week 19	4	Ben
Place Tower Upright	Week 14	4	Ben
GUI for Turbine Output	Week 24	1	David/Matt
Meet with REC to confirm connection	Week 24	3	All
Create Final Presentation	Week 29	3	All
Create a blueprint packadge	Week 19	2	Tate

3.2 OTHER RESOURCE REQUIREMENTS

Other resources our group will need includes

- Steel
    - The steel is needed to construct the tower of the turbine and the nacelle that holds the generator in place
- Secondary motor
    - A secondary motor is needed to test our generator with. This motor will be able to start our generator and from that we can get readings for the induction generator about starting speed and max output.
- Time
    - Time is a very important resource that is needed that shouldn't be overlooked. Being able to have time to test the generator and build all the blueprint we desire is important.

3.3 FINANCIAL REQUIREMENTS

All parts are being provided and are to be determined. As of right now general idea of cost is around $15,000. This does not include labor that was done by client Ron Zickefoose or the use of the crane which was provided for free. A list of parts without costs has been gathered so far.

item	**amount #**	**price ($)**
total as of now		$15,000.00
Turbine Structure		
Generator	1	883
Tower		
Blades		
Gearbox		
Cables		
Grounding Cables		
Power Cables		
Contollers		
xBee	2	
micro controler		
anomiot		
rellays		
battery assembly		
Misc Items		
Crane	10	200 (per hour)
Secondary Motor		500

Figure 10-A list of parts needed for the wind turbine

3.4 PROJECT TIMELINE

Task	Task Deadline	Work Load (hrs per week)	Task Leader
Weekly Meetings	-	1+	All
Meetings with Nick	-	1	All
Meeting with Advisor	-	1	All
Meeting with Turbine Owner/Builder	-	1	All
Weekly Progress Reports	-	1	All/David
Project Plan	Week 15	4	All
Design Document	Week 29	4	All
Reflection	-	1	All
Lightning Talk Preperation	-	1	All
Research Islanding	Week 3	2	All
Research Inductor Motors	Week 3	2	All
Get Wind Data from Local Airport	Week 6	2	Melissa/Tate
Create Blueprints of the Sit Map	Week 3	3	Ben
Create Blueprints of Foundation	Week 5	3	Ben/David
Create Blueprints of One-line Diagram	Week 6	4	Ben/David
Create Blueprints of 3-line Diagram	Week 7	3	Ben/David
Create Blueprint of Control Wiring	Week 8	3	Ben/David
Create Blueprint of Tower (3D CAD)	Week 9	4	Melissa/David
Create Blueprint of Blade 3D (CAD)	Week 10	4	Melissa/David
Creat Blueprint of Motor (3D CAD)	Week 12	4	Ben/David
Tail Vane Module	Week 11	5	Tate/Matt
Predict Power Output from Turbine based off Wind Veocity	Week 8	2	Melissa
Simulate Generator Simulink	Week 10	4	Melissa/Matt
Testing the Generator	Week 17	5	David/Ben
Mechanically disconnect generator from naccell	Week 7	3	Ben
Reconnect generator to a testing motor	Week 8	3	Ben/David
Built motor mount	Week 9	4	David
Research/Buy Shaft Coupler	Week 10	2	Matt/Ben
Testing Base Motor Configurations	Week 12	5	David/Ben
Testing Power Backflow	Week 13	5	Tate/Matt
Testing Max Power	Week 17	5	David/Ben
Contact REC for requiremens	Week 6	1	Ben
Get Paperwork for REC	Week 8	1	All
Contact engineer to get clearence of tower	Week 10	2	Ben
Have PE sign off on blueprints	Week 18	2	All
Put Motor onTurbine	Week 19	4	Ben
Place Tower Upright	Week 14	4	Ben
GUI for Turbine Output	Week 24	1	David/Matt
Meet with REC to confirm connection	Week 24	3	All
Create Final Presentation	Week 29	3	All
Create a blueprint packadge	Week 19	2	Tate

Figure 11- Our Project Timeline

4 Closure Materials

4.1 CONCLUSION

The client Ron Zickefoose designed and is building a wind turbine on his property. That will not cause any islanding on the power grid. The wind turbine should be able to supply enough power for our client's needs, and enough to sell back to the utility. Proving that the wind turbine will not cause any islanding issues with the utility tests will be done on the induction motor used. There will be a detailed research, analysis, description of the capabilities, limitations of the induction motor. This research will allow for the wind turbine to be hooked up to the grid and supply power and income to our client.

4.2 REFERENCES

[1] https://en.wikipedia.org/wiki/Induction_motor

[2] https://en.wikipedia.org/wiki/Islanding

[3] https://www.allianz.com/en/about_us/open-knowledge/topics/environment/articles/100505-top-ten-wind-power-countries.html/#!ma37b41a1-2c4f-4574-8544-66fccab6c005

[4] https://en.wikipedia.org/wiki/Wind_power_in_Iowa

[5] https://en.wikipedia.org/wiki/Squirrel-cage_rotor