EG2340 Wind Power Systems - Team Project 2015

By Lennart Söder, October 1, 2015

Introduction

An investor would like to investigate the options for the most profitable wind power investment. He asks 16 different teams to perform pre-feasibility studies for different wind power projects. Each team should have three to four participants.

Team Name	Total Wind Farm Size [MW]	Wind Turbine Size [kW]	Wind Speed Data	Location
Team 1	20	500–800	Byxelkrok	Onshore
Team 2	40	1000–2000	Byxelkrok	Mountain
Team 3	100	1000–2000	Byxelkrok	Offshore
Team 4	140	1500–2500	Byxelkrok	Onshore
Team 5	160	1000–2000	Maglarp	Onshore
Team 6	180	2500–3600	Maglarp	Mountain
Team 7	240	1500–2500	Maglarp	Offshore
Team 8	280	3000–5000	Maglarp	Onshore
Team 9	320	2500–3600	Näsudden	Mountain
Team 10	460	3000–5000	Näsudden	Onshore
Team 11	520	2500–3600	Näsudden	Offshore
Team 12	640	1500–2500	Näsudden	Onshore
Team 13	760	2500–3600	Ringhals	Offshore
Team 14	800	2000–3000	Ringhals	Onshore
Team 15	900	3000–5000	Ringhals	Offshore
Team 16	1000	3000–5000	Ringhals	Onshore

All wind data are stored in one file 'ormnbr_data.mat' and how to read the data is found in the file 'Check_data_2015.m'. These two files are available form the home page. The measuring height was 96 meters for Maglarp, Näsudden and Ringhals, but 113 meters for Byxelkrok.

The project includes the following stages:

1. A final report with a maximum of **20 pages** per team. Reports should be submitted through the course web page on KTH Social. Choose "Submission project" below "Assignments" in the menu to the left. From this page you can upload your report latest Monday December 7, 2015, noon (12.00). You can find instructions for the report at the end of this document.
2. A team presentation of 10–15 minutes, which will be held on Monday December 14, 10-12, 2015. The presentation will be followed by questions from the audience, and from another team which will have read the report and prepared questions. This means that every team will get a copy of the final report of another team, and should prepare questions on it beforehand.

Tasks

This is a research exercise, so you should look outside the course material for further information. Books, journals, newspapers and internet, as well as personal and email communication with industry or academic experts are acceptable references. Reading reports from operational wind farms can help you understand the choices that have to be done. Complete tasks A–E, but also include anything you consider important and / or interesting for an investor, and stay within the page limit.

A Analysis of Available Wind Turbine Technology

Instructions

- Compare the technical designs of **four** wind turbines from different wind turbine manufacturers. You can choose any turbines within the wind turbine rating limits defined for your team.
- Discuss the main features of the wind turbines, e.g. reactive power and fault ride through capabilities, power curves, weight etc., if available. Also discuss different foundation options and other issues related to the installation, e.g. issues related to the location.
- Choose **two** turbine models for further examination, and explain your reasons for choosing them.

Details from the comparison should be summarised **within one table**, and include a discussion of **not more than two** pages of text.

Hints

Some wind turbine models can be found at

- http://www.wind-energie.de/en/
- http://www.windustry.org/your-wind-project/wind-energy-companies/wind-energy-companies.

B Wind Data Analysis

Instructions

- Siting:
  - Nominate a possible location in the world that fits with the requirements for your group (onshore, offshore, mountain, see table above) for the wind power investment.
  - Design two possible layouts for the wind farm. Each layout should take into account both the topological layout of the turbines, for example which direction they face and how they are sited with respect to each other, and the electrical layout, for example the main electrical components in the internal grid of the wind farm and the electrical connections between the turbines. Explain briefly why you have chosen the location and layouts, taking into account environmental aspects, grid connection aspects and economical aspects.
- Assume that the wind speed data specific for your group has been measured at this location[1], at the height as stated above for the respective sites. Assume that all wind directions are as common. Calculate the annual energy production of the wind farm for the **two layouts** and the **two wind turbine models** chosen in the section A, by making appropriate assumptions about the wind turbine availability, the wake effect between the turbines, the tower height and the roughness factor[2].
- Finally, for the rest of the study, choose a wind turbine from the two models you kept from section A and a layout from the two you proposed and explain your choice.

[1] This means that you do **not** have to look for a location whose wind conditions match the data you were given.

[2] It is possible to use an unvalid "trick" here: take two locations and the same measured wind speed data, the location with the highest roughness factor will get higher wind speeds because of the logarithmic profile. This is not a valid argument for choosing a location. In short: do not choose a location because its roughness factor gives rise to higher wind speeds with the given data.

C Network Integration Issues

In this part, you are asked to choose a proper point to connect the wind farm to the grid. The grid that all teams will use for analysis of network integration is shown in figure 1 (this is a schematic of the grid to which you will connect your wind farm). The data for each points to which the wind farm may be connected is given in table 1.

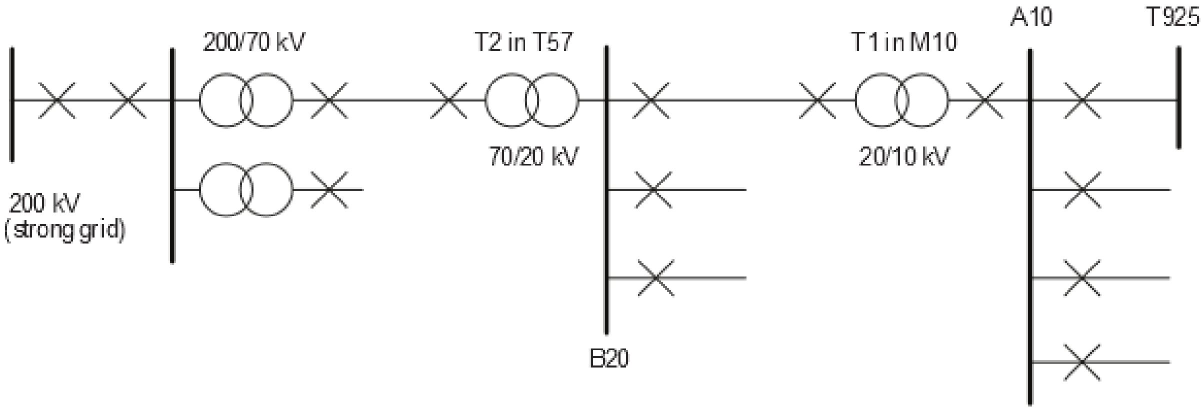

Figure 1: Network

Table 1: Data for the possible connection points

Point number	Connection point	Short-circuit capacity S_k (MVA)	Load/line/phase (A)	Number of lines
1	T925	500	150-370	2
2	A10	900	150-390	4
3	20 kV side of T1 in M10	1100	130-345	2
4	B20	1300	130-345	2
5	70 kV side of T2 in T57	1300	130-345	2
6	70 kV side of 200/70 kV transformer	1800	120-325	1
7	200 kV side of 200/70 kV transformer	2200	42-114	2
8	Strong grid	–	84-228	1

The following assumptions can be made for the calculations:

- the grid can be assumed to be purely inductive,
- load power factor can be assumed 0.9 inductive everywhere,
- the installed wind farm is controlled to keep a power factor equal to 1,
- voltage limits are $\pm 10\%$ for voltages above and including 70 kV, and -10%, $+6\%$ for voltage levels below 70 kV,
- the higher the short-circuit capacity of the connection point the higher the price for connection at this point.

Instructions

- Calculate the maximum capacity of a wind farm that can be connected to each of the connection points.
- Choose a location in the network where it is possible and most economically efficient to install your wind farm. Include all calculations and relevant curves which support your choice.
- What other issues need to be considered when choosing a connection point?
- What would happen if the wind farm was able to generate reactive power? Assume that the power factor of the wind farm can be choosen to be 0.95-1.00, capacitive or inductive, and calculate the maximum capacity of the wind farm that can be connected in this case.

Notes and hints

- The voltage limits are given in terms of the nominal voltages, which are given by the transformer ratings.
- The network at every connection point can be represented by a Thévenin equivalent. The nominal voltages can be used for Thévenin voltages U_{th}.
- The load currents are given per line and per phase in table 1. The total load is calculated approximately as

$$S_{load} = n\sqrt{3}U_{th}I_{load},$$

  where n is the number of lines. From this P_{load} and Q_{load} are calculated as in Assignment 2. Also, the load currents given in table 1 can take on all values in the given range, not just the extreme values.
- It is not enough to only consider the lowest load values.
- Using the simplifications above, the network can be simplified to a two node equivalent, and the voltage can be calculated using equation (5.29) from *Static Analysis of Power Systems*.

D Economic Analysis

Instructions

- Describe, if any, the support scheme for wind power that is used at the location you chose.
- Calculate the life cycle costs of your project over a lifetime of **20** years. Include the cost of equipment, installation, maintenance, dismantling etc. in your analysis and make appropriate assumptions about the price of the power. Do not forget to include incomes from support schemes.
- Include a sensitivity analysis and summarize your findings.

See Chapter 11.6 in *Wind Energy Explained, Theory, Design and Application* [1] for an overview of life cycle analysis.

Notes and hints

- It is advised to use the software RETScreen to do the economic analysis. RETScreen is a free Excel-based program and can be found at www.retscreen.net. It requires Windows and Excel.

E Discussion

Discuss the feasibility of your project.

Instructions for the report

A portion of the final mark will depend on the structure and layout of the final report. The report must be written in English and should be well structured (it is advised to use the different tasks, sections A to E, as the different sections for the report). The layout should be consequent throughout the report. The page limit of 20 pages includes everything (title page, table of contents, main content, bibliography) but appendices.

The following elements must be found in your report:

1. names of team participants,
2. a table of contents,
3. a summary,
4. a list of all references: you have to give references for all figures and facts (for example electricity prices and prices to build the turbines),
5. definitions of all symbols introduced in the calculations,
6. page numbers.

Check this list before you hand in your report to make sure that your report fulfill these requirements. Please note that the reports will be run through an antiplagiarism tool that searches for matches between the reports and sources available on the internet.

Project setup

- The teams are formed randomly.
- Once the groups are formed, they should distribute the tasks and plan the steps to complete the project. The result of this schedule should be uploaded on couse home page latest 25th of October, 18.00.
- The questions about the project can be asked through email with the project assistant. However, group meetings can also be arranged, if needed. The date for the meeting is decided through email with the project examiner.
- Each group is given another group's report to review. The report to review is sent to the group on December 7, 18.00
- The review report (1-2 pages) includes the reviewer group name, the reviewed group name, and the comments arised.
- One week after the hand-in deadline is the presentation day. Each group should prepare 10-15 minutes presentation. In the same day (latest 8 AM), the groups should upload the review report on course home page.
- The presentation will be followed by questions from the audience, and from the reviewer group.
- This is a pass/fail project (1.5 hp).

Important deadlines

Date	Description
September 25	The groups were announced
October 25, 18.00	Upload project plan
Monday December 7, 12.00, 2015	Final report: upload the report to course home page.
Monday December 7, 18.00, 2015	The report to be reviewed will be sent out by e-mail
Monday December 14, 8.00, 2015	Upload the review report to course home page.
Monday December 14, 10-12, 2015	Final presentation. Compulsary participation.

Contact

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References

[1] J. F. Manwell, J. G. McGowan, and A. L. Rogers. *Wind Energy Explained*. John Wiley & Sons Ltd., 2009.