KTH Electrical Engineering

EG2040 Wind Power Systems
Team Project 2013

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	Set 1	Onshore
Team 2	40	1000–2000	Set 1	Mountain
Team 3	100	1000–2000	Set 1	Onshore
Team 4	140	1500–2500	Set 2	Offshore
Team 5	160	1000–2000	Set 2	Onshore
Team 6	180	2500–3600	Set 2	Mountain
Team 7	240	1500–2500	Set 2	Onshore
Team 8	280	3000–5000	Set 2	Mountain
Team 9	320	2500–3600	Set 2	Offshore
Team 10	460	3000–5000	Set 3	Offshore
Team 11	520	2500–3600	Set 3	Onshore
Team 12	640	1500–2500	Set 3	Offshore
Team 13	760	2500–3600	Set 2	Offshore
Team 14	800	2000–3000	Set 3	Onshore
Team 15	900	3000–5000	Set 3	Offshore
Team 16	1000	3000–5000	Set 3	Onshore

Links to the data sets:

- Set 1: http://www.eps.ee.kth.se/EG2040/Set1.xls
- Set 2: http://www.eps.ee.kth.se/EG2040/Set2.dat
- Set 3: http://www.eps.ee.kth.se/EG2040/Set3.dat

The project includes the following stages:

1. A final report with a maximum of **20 pages** per team. A paper copy of the report should be handed in, and an electronic copy sent to camille.hamon@ee.kth.se, by 26 April 2013, 5 pm (17.00). 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 one of 6, 7, 8, 13, 14, 16 and 17 May 2013. 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 a height of 10 m. Wind coming from the North has an angle of 0°, East of 90°, South of 180° and West of 270°. 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.

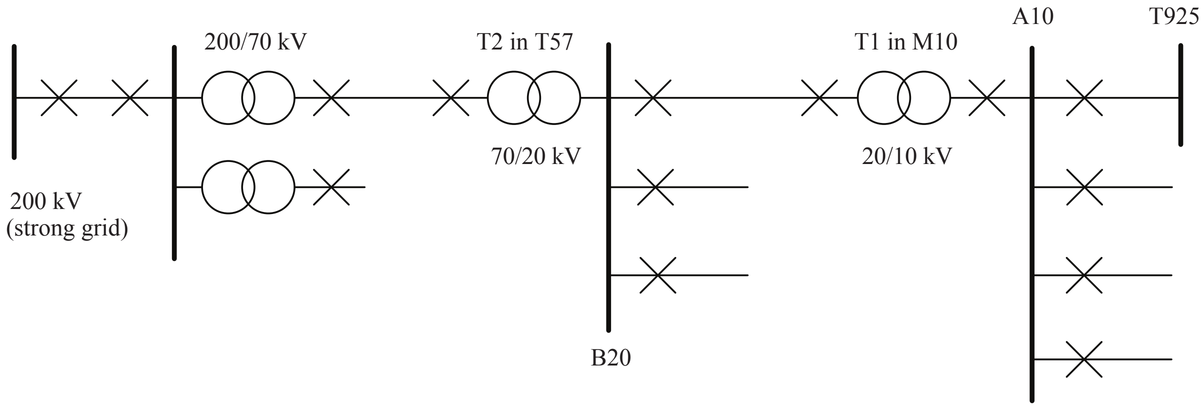

Figure 1: Network

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	450	150-370	2
2	A10	800	150-390	4
3	20 kV side of T1 in M10	1000	130-345	2
4	B20	1200	130-345	2
5	70 kV side of T2 in T57	1200	130-345	2
6	70 kV side of 200/70 kV transformer	1700	120-325	1
7	200 kV side of 200/70 kV transformer	2000	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 is 0.95, 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.

Important deadlines

Date	Description
8 February	The groups will be announced
26 April, 17.00	Final report: hand in a paper copy and send an electronic copy to camille.hamon@ee.kth.se.
22 April – 3 May	Register for the oral presentation (https://www.ee.kth.se/lab?course=EG2040).

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.