PARK- User's Guide. A PC-program for calculation of wind turbine park performance

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A PC-program for calculation of wind turbine park performance

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Contents

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1 Introduction

The *PARK* computer program was made in order to get a simple analysis tool for the design of wind farms, able to run on a personal computer. *PARK* calculates power output from individual wind turbines at specified wind conditions as well as annual production if wind climatological data are available. The program is not able to compute blade loads, turbulence levels or power fluctuations in the grid.

The following text is not a full documentation or manual for the *PARK* program, but it contains some hints and information, which might be useful when running the program for the first few times. Part of the text is also available as an on-line help file.

The *PARK* computer code is based on a mathematical model, of the wake behind a wind turbine, developed by N.O. Jensen, Risø. This model uses the momentum-deficit theory to predict the flow field in a very simple way, as the wake is supposed to expand linearly behind the rotor. Thus the only variables are the initial velocity deficit at the start of the wake and the wake decay constant, which is the rate of expansion (break-down) of the wake.

Because the *PARK* model is two-dimensional, only turbines of the same hub height can be calculated, and the terrain must be relatively homogeneous in order to prevent speed-up effects etc.

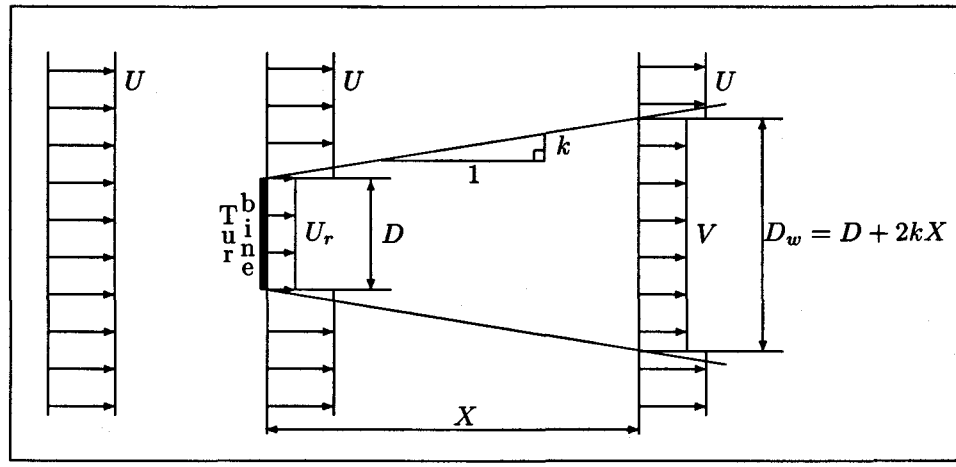

Figure 1. Flow field used by the program to calculate wind turbine output.

The reduced wind speed is calculated by the formula:

$$V = U\left[1 - \left(1 - \sqrt{1 - C_t}\right)\left(\frac{D}{D + 2kX}\right)^2\right]$$

where $\sqrt{1 - C_t} = U_r/U$, V is the wind speed in the wake, U the undisturbed wind speed, C_t the turbine thrust coefficient, D the rotor diameter, X the axial distance from the rotor to the point for the calculation, and k is the wake decay constant.

2 Installation

The *PARK* program is furnished in compressed form and should be installed in a similar way as the WASP program:

```
C:\> md park
C:\> cd park
C:\PARK> a:installp
```

if the diskette is in drive `A:` and the files should reside in `C:\PARK`. This program detects automatically the graphics card in your computer and you should thus be able to run it right away.

The program can also be installed on a floppy disk using the procedure outlined above. However, running the program from a floppy disk is considerably slower than the hard disk, since the program performs relatively many input/output operations with external files.

With the exception of your own data files, all the files used by *PARK* must be located in one and the same directory.

3 Main Menu

When you type the command `PARK` at the DOS prompt, the computer will load the default data files etc., and then display the main menu on the screen.

3.1 Parametres

In this menu you can set the constants of the parameter file, including graphics screen set-up, wake decay constant and number of wind direction sectors.

For most screens the program will automatically detect which graphics driver to use – if its number is set to '0' in the parameter file. If this doesn't work, you can manually choose the driver and mode you want to use.

The wake decay constant k is defined as:

$$k = \frac{A}{\ln(h/z_0)}$$

where A is a constant ($A \approx 0.5$), h is the hub height, and z_0 is the roughness length. Normally, a wake decay constant of 0.05 to 0.10 will give satisfactory results; the smaller the estimated turbulence intensity, the smaller a constant should be used. Please note, that differences in surface roughness can make it necessary to use sector-specific decay constants!

The number of steps per sector defines how many degrees the program steps between each wake calculation. It should be chosen such that the direction step becomes lower than about 5–8 degrees.

It is possible to take into account the influence of air density on the power output by redefining the height above sea level and the average temperature of the site. It is assumed that the power curves for the turbines are valid for standard conditions, ie 0 m a.s.l. and 15°C.

3.2 Data

The necessary input data includes:

a) Wind turbine characteristics, ie power curve, thrust coefficient curve, hub height and rotor diameter.

b) Coordinates of each wind turbine in the park.

c) Meteorological data for the site.

The thrust coefficient may be difficult to find in standard technical data. It can be computed by a rotor simulation program, estimated from data for similar wind turbines, or measured directly as tower bending moment. As a help the program is able to generate an approximate 'standard thrust coefficient curve'. The thrust coefficient C_t is defined as:

$$C_t = \frac{2 \times F_T}{\rho \times \pi \times R^2 \times U^2}$$

where F_T is the thrust force, ρ is the density of the air, R is the rotor radius, and U is the undisturbed wind speed.

The `VIEW` option shows a graph of the wind turbine power and thrust coefficient curves, as well as a map with the turbine positions. The turbines are represented by circles with a diameter approximately corresponding to the rotor diameter. The turbine coordinates are given in metres with the X-axis pointing to the east and the Y-axis pointing to the north. You can enter rows of turbines if the turbine positions are equidistant along a straight line. *The model is limited to handle arrays with internal distances larger than about four diametres.*

The meteorological data are given as the parametres of a Weibull distribution, modelling the real wind speed distribution of the site (Troen and Petersen, 1989). The Weibull parametres are given for each of the direction sectors together with the probability of the wind coming from each sector. *Please check that the sum of the frequencies is 1!* Site data can be given for different points in the wind farm, taking into account the possible variation of roughness, and can be transferred directly from a WASP result file (including one or more points, max. 100). The WASP file can be in the .DMP or the .RSF format. Remember, that the hub height and the height for the WASP results should be identical.

The wake decay constant can, optionally, be inserted sector wise by the .DEC-files. The .DEC-files are created in the `Data` option by typing ⟨*⟩ and can then be entered as roughness lengths or decay constants.

You are able to execute DOS commands from the *PARK* program by selecting the `MsDos` option. Be sure, that you are in the right directory before returning to the main menu! If you press ⟨*Return*⟩ or type EXIT at the DOS prompt you are back in the program. Remember to reload data if they have been edited in DOS.

4 Calculation Menu

Here you can choose between different calculations of the instantaneous power output at various wind speeds and directions, or you can have the annual production of each turbine as well as the output compared to the situation without wake losses.

The results are dumped in a result file `PARK.RES`, which is displayed on the screen when the calculation is done. You can jump through this file, using the arrow or the ⟨*PgUp*⟩/⟨*PgDn*⟩ keys. ⟨*Home*⟩/⟨*End*⟩ (or ⟨*Ctrl*⟩⟨*PgUp*⟩/⟨*PgDn*⟩) will bring you to the beginning or the end of the file, respectively. You may return to the main menu by pressing the ⟨*Return*⟩ key. *The file is overwritten with new results after a calculation has been carried out.*

With the `List` option you can have a look at the last result file or any other file you specify.

4.1 Editing commands

You can delete or insert wind turbines on the map if you choose the `crosshair` option. The cross-hair is moved with the arrow keys: ⟨*Shift*⟩⟨*arrow*⟩ will move the cross-hair in steps of 10. You return to the menu by pressing ⟨*Return*⟩ and the positions are now updated with the inserted/deleted turbines.

The `turn` option lets you turn the entire wind park relative to the present orientation. Clockwise direction is positive.

`Move` is used to change the reference point of the coordinate system or to change the internal distance between the wind turbines.

All these operations are relative to the present origin of the coordinate system. Remember to save the modified turbine positions, using the `save` option in the main menu.

If you prefer, you can edit directly in the turbine position file (with default extension `.POS`). The format of this file is (cf. `DEFPARK.POS`):

N_T			Number of points with wind statistics.
X_1	Y_1		Coordinates of point 1
A_1	C_1	F_1	Weibull parametres and frequency, sector 1.
⋮	⋮	⋮	
A_M	C_M	F_M	Weibull parametres and frequency, last sector .
X_N	Y_N		Coordinates of point N
A_1	C_1	F_1	Weibull parametres and frequency, sector 1.
⋮	⋮	⋮	
A_M	C_M	F_M	Weibull parametres and frequency, last sector
N_1	X_1	Y_1	Index number, X and Y coordinates, first turbine
⋮	⋮	⋮	
N_N	X_N	Y_N	Index number, X and Y coordinate, last turbine

where N_* are integer numbers and X_*, Y_*, A_*, C_*, and F_* are reals. The numbers on one line should be separated by one or more blank characters (spaces) – not commas. Use leading zeros in front of decimal points.

The format of the wind turbine data file (default extension TRB) is (DEFTURB.TRB):

R	H	Radius and hub height for rotors.
n		Number of points in power curve data set (max. 40 points)
V_1	P_1	Wind speed [m/s] and power [kW], first point.
⋮	⋮	
V_n	P_n	Wind speed [m/s] and power [kW], last point.
m		Number of points in thrust coefficient data set (max. 40 points)
V_1	$C_t(1)$	Wind speed [m/s] and C_t, first point.
⋮	⋮	
V_m	$C_t(m)$	Wind speed [m/s] and C_t, last point.

where n and m are integers and R, H, V_*, P_*, and $C_t(*)$ are real numbers. The numbers on one line should be separated by one or more blank characters (spaces) – not commas. Use leading zeros in front of decimal points.

5 Miscellaneous Information

Be careful at the following points:

- Remember, that the wake decay constant is a function of the turbulence intensity and thus the roughness of the terrain. A constant of 0.03 to 0.05 for water and 0.07 to 0.1 for farmland is suggested.
- Check, that no turbines are closer to each other than about four diameters.
- For very large arrays (the model can handle up to 100 turbines) there might be a larger reduction in power than computed, due to the influence on the general roughness description for the site caused by the turbines.
- The model is not able to handle speed-up and slow-down effects, which may be important for wind parks in mountainous terrain. The wakes are supposed to follow the contours of the landscape.
- Check that the power and thrust coefficient curves are correct in the entire range from 0 to 30 m/s. The thrust coefficient must not exceed 1.

List of necessary files (must be in the same directory):	
PARK.EXE	Main program
HELP.TXT	Online help text
PARKPARA.DAT	Parameter file
*.BGI	Graphics driver(s)
DEFTURB.TRB	Default wind turbine data
DEFPARK.POS	Default turbine position file

5.1 Hardware requirements

PARK will run on IBM Personal Computers (PC, XT or AT), IBM Personal System/2 and true compatibles with PC-DOS or MS-DOS operating system version 2.0 or higher, one double-sided disk drive ($5\frac{1}{4}''$ or $3\frac{1}{2}''$) and at least 256 kbytes memory (RAM). An 8087 or 80X87 mathematical co-processor is strongly recommended.

The file `WASP.TOC` on the diskette contains a list of the files necessary to run *PARK*. The disk may also contain a `READ.ME` file with the latest information.

5.2 Errors

If you encounter any errors during program execution, please report these to the Department of Meteorology and Wind Energy, Risø National Laboratory. You are also welcome to send suggestions for program modifications.

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Abstract (Max. 2000 char.)

PARK is a PC-program for calculation of wind turbine park performance, based on a two-dimensional mathematical model of the wake behind a wind turbine. The model uses momentum-deficit theory to predict the flow field and the wake is supposed to expand linearly behind the rotor. The only variables are the initial velocity deficit at the start of the wake and the wake decay constant, ie the rate of expansion (break-down) of the wake. The program estimates the power output from individual wind turbines at specified wind conditions as well as the annual production if wind-climatological data are available.

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