The Advanced Knowledge Provider
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風力發電技術研習會

陳正輝
皮托科技股份有限公司

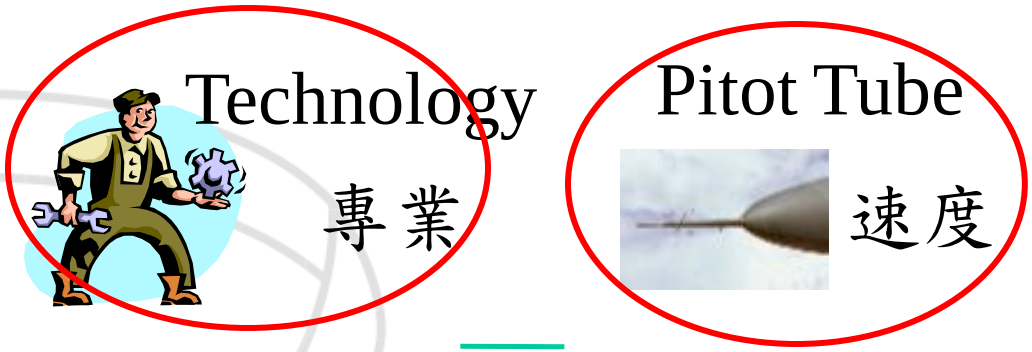
2010/05/27
大仁科技大學

Session I：綠能相關硬體設備介紹

- 綠能與電力電子介紹
- 太陽能、風能、燃料電池等相關實驗硬體設備
- 能源管理系統介紹(Inverter)
- 遠端監控、無線感測網路(Zigbee)相關應用

公司介紹

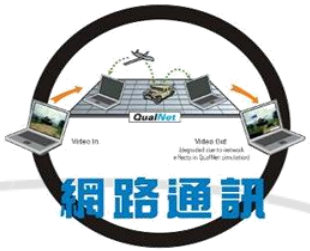
- 成立於民國81年
- 本公司位於中台灣的彰化市，由於地理位置之優勢，所以我們能提供北、中、南的客戶最快速的服務。



PITOTECH

The Advanced Knowledge Provider

公司介紹



本公司的服務項目包括：提供**軟體顧問**、**專業訓練**及**產品銷售**等服務等。

專業的技術人員，提供最新的科技知識與產品，以及最好的服務品質。

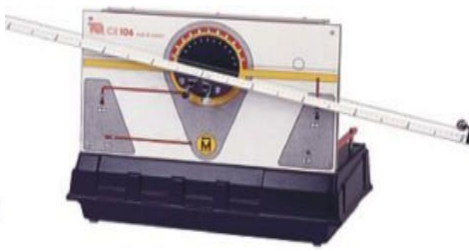
提供solution 而非單一產品線

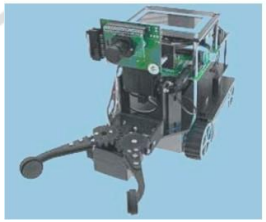
流體力學實驗室

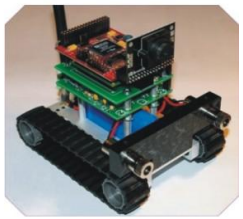
- 泵串並聯實驗設備
- 流量量測實驗設備
- 壓力量測實驗設備
- 風洞實驗設備
- 流體機械實驗設備
- 管路能量損失實驗設備
- 綜合水利實驗
- 雷諾數實驗設備
- 壓力中心實驗設備
- 自由與強制渦流實驗設備
- …

自動控制&機器人發展實驗室

- 各類機器人控制實驗設備
- 類比與數位基礎控制實驗系統
- 泛用型MATLAB即時控制系統
- 數位倒單擺控制實驗系統
- 示線性磁浮球控制實驗系統
- MIMO直昇機控制系實驗系統
- 水槽液位控制系統
- SIS 感測與量測實驗裝置
- …



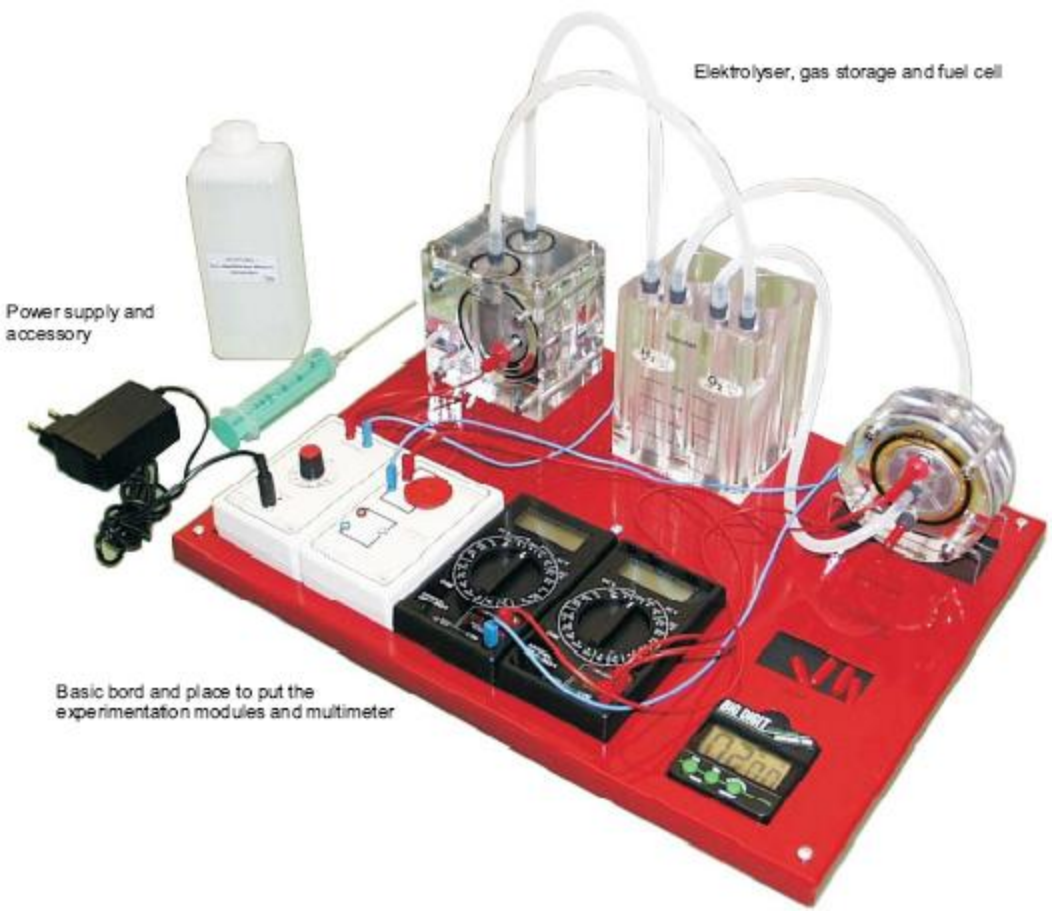




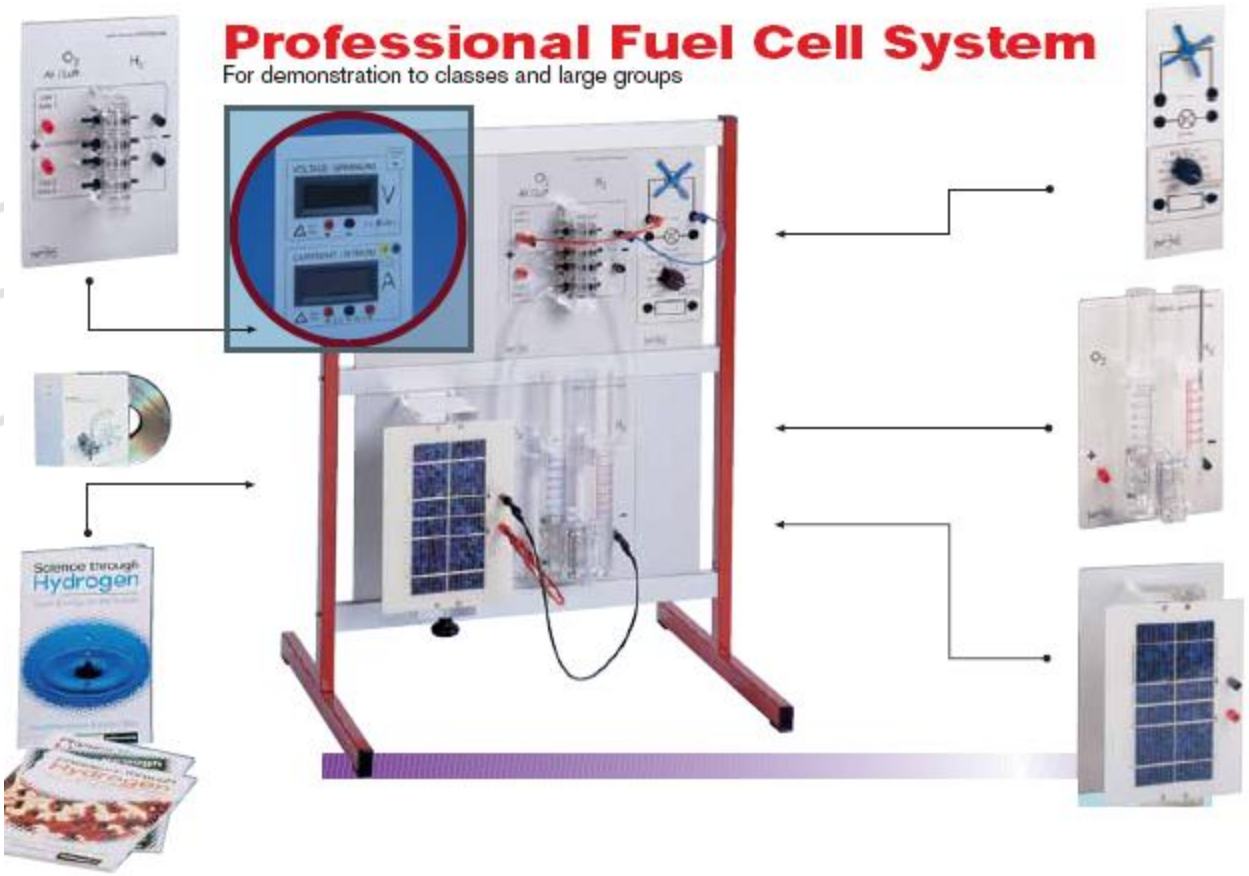
綠色能源實驗室

- 燃料電池電力供應訓練台
- 太陽能與燃料電池訓練台
- 燃料電池輔助普教系統
- 燃料電池模型車組
- 氫氣燃料電池實驗組
- 太陽能光電實組
- 太陽能電池教學實驗裝置
- 太陽能吸教式冷凍機實驗
- 風力電力實驗設備
- 風力發電機系統
- 風力發電實驗組
- …

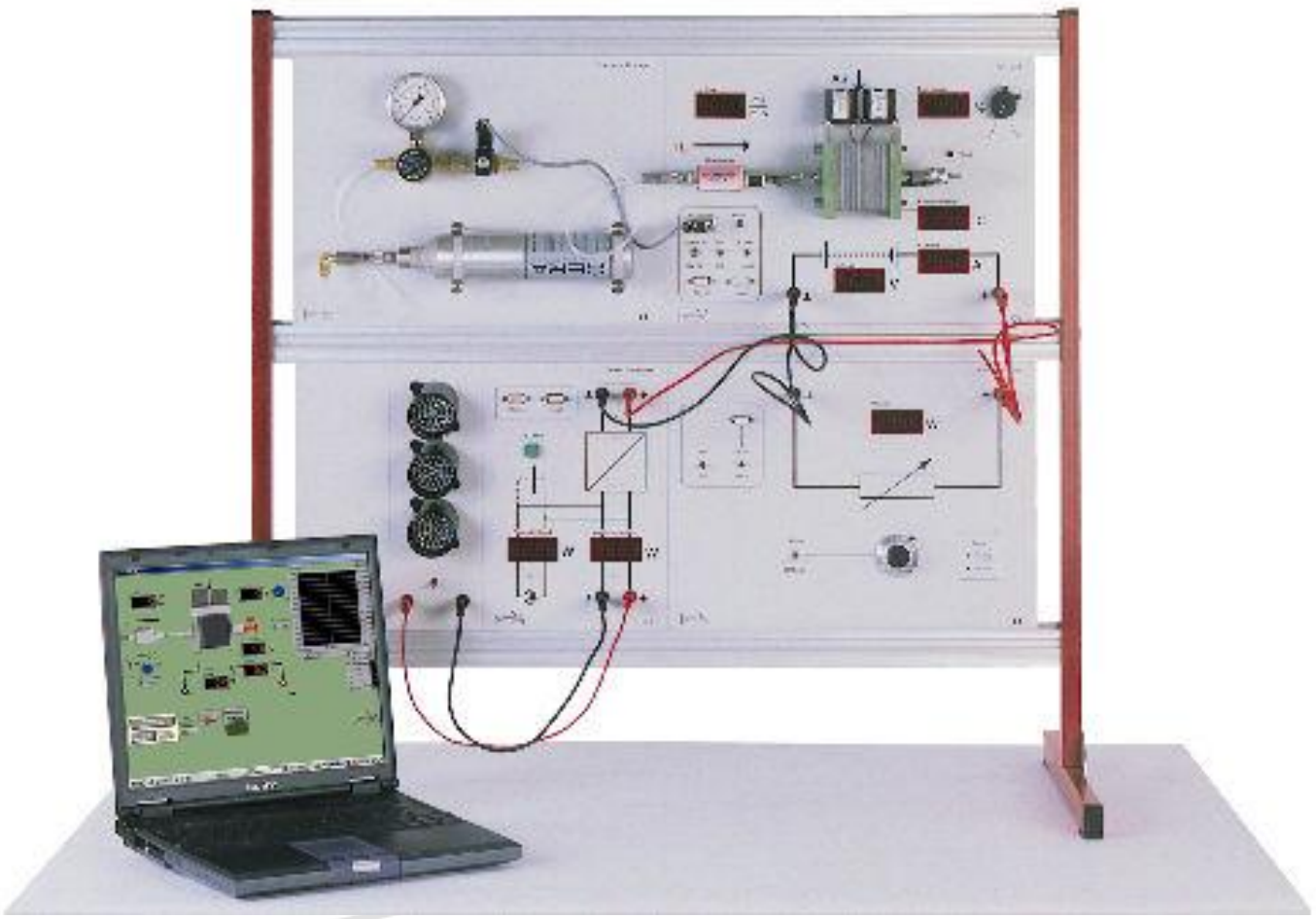
燃料電池實驗設備


Elektrolyser, gas storage and fuel cell
Power supply and accessory
Basic bord and place to put the experimentation modules and multimeter

燃料電池實驗設備


Professional Fuel Cell System
For demonstration to classes and large groups
Science through
Hydrogen

燃料電池實驗設備

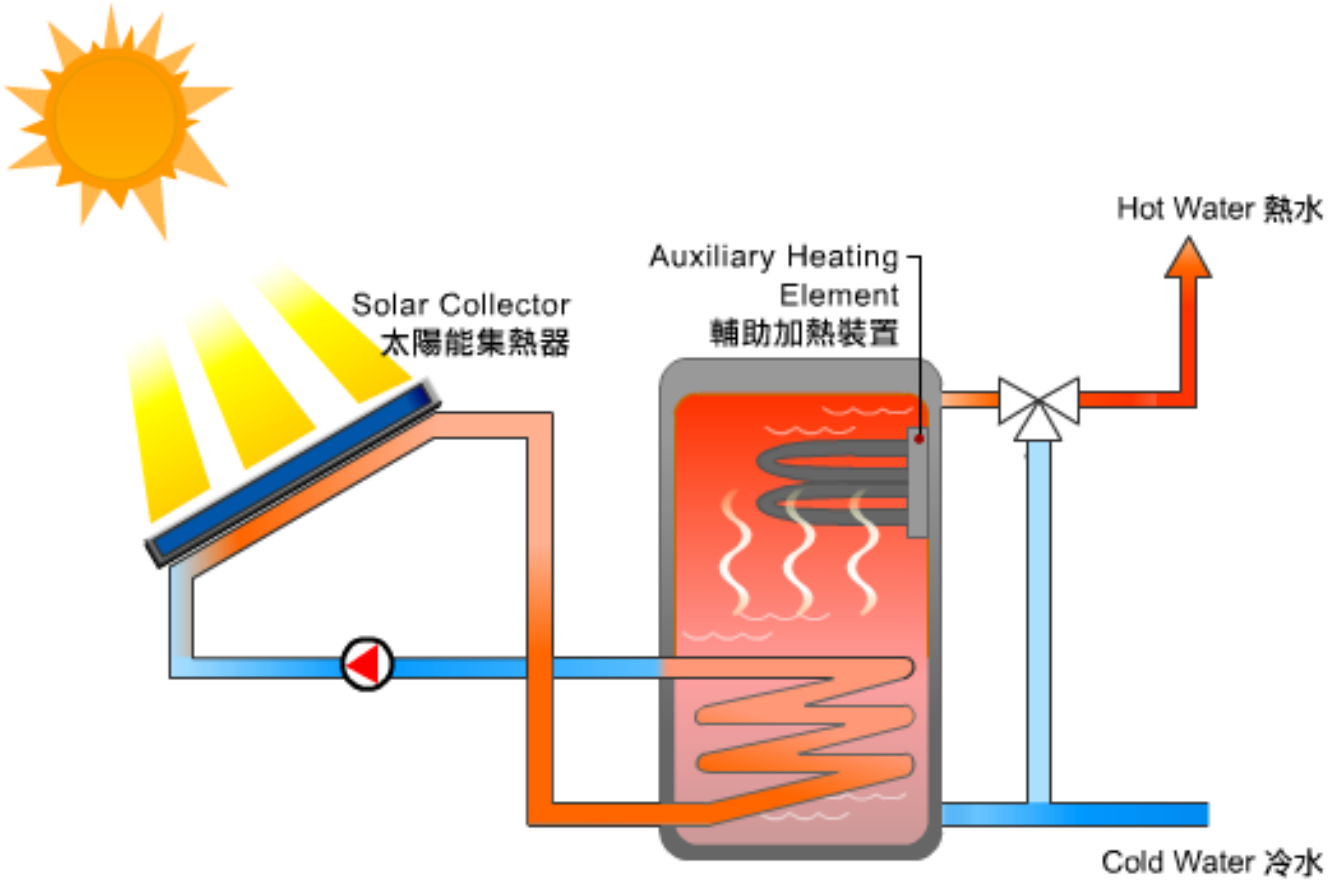


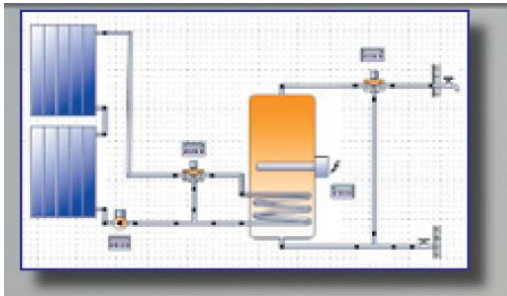
燃料電池實驗設備

Hydrogen Fuel Cell Model Car

For grades 5 – 10 science classes

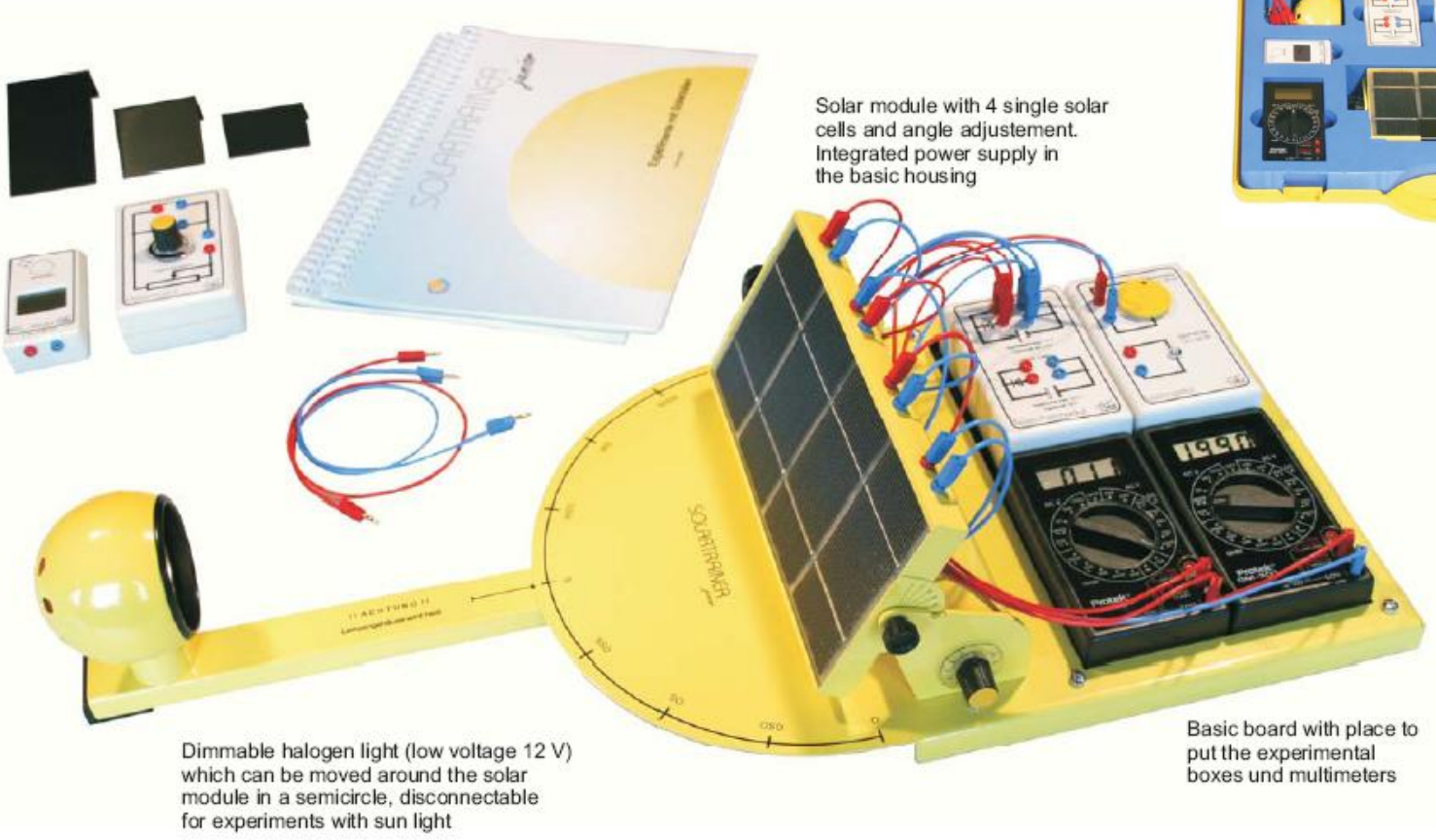
太陽能集熱器設備原理





The convenient modular unit construction system allows the combination and parameterisation of different system components through simple menu prompts: if you are confident enough in the use of Windows programs you'll have no trouble finding your way around in the new Polysun. A template collection including a wide range of proven system concepts will be provided with the software.

太陽能電池特性實驗設備



太陽能孤島與併網實驗

1.5KW高功率太陽能教學實驗系統

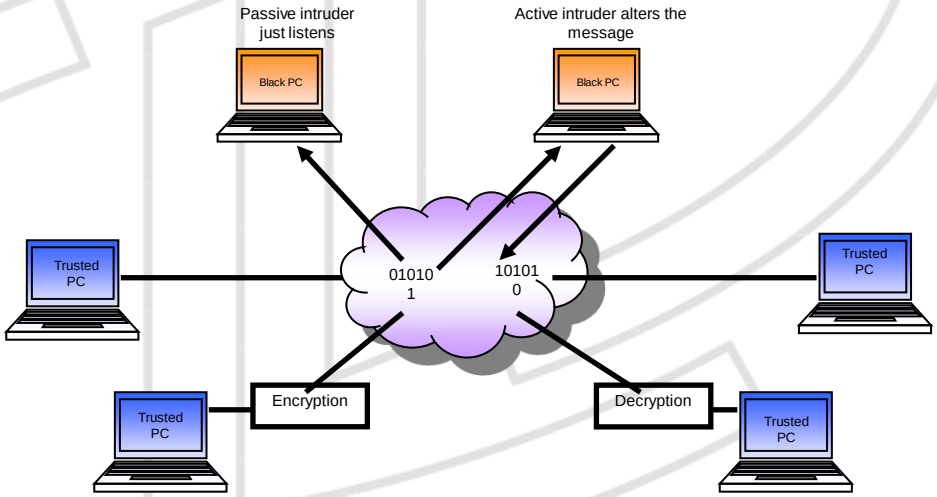
實驗課程大綱：

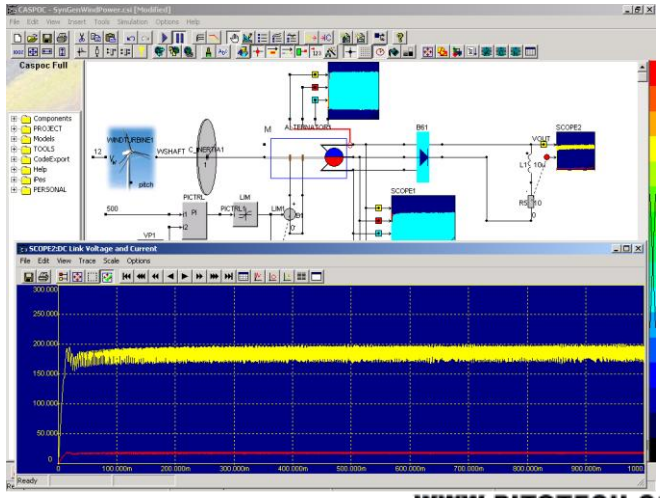
- 系統簡介
- 單晶太陽能電池特性實驗
- 多晶太陽能電池特性實驗
- 太陽能電池串聯特性實驗
- 太陽能電池並聯特性實驗
- 日照強度對太陽能電池特性影響實驗
- 入射角對太陽能電池特性影響實驗
- 電池充電與放電特性實驗
- 變頻器與交流負載特性實驗
- 太陽能發電系統實驗
- 太陽能電池模擬與應用

太陽能教學實驗系統

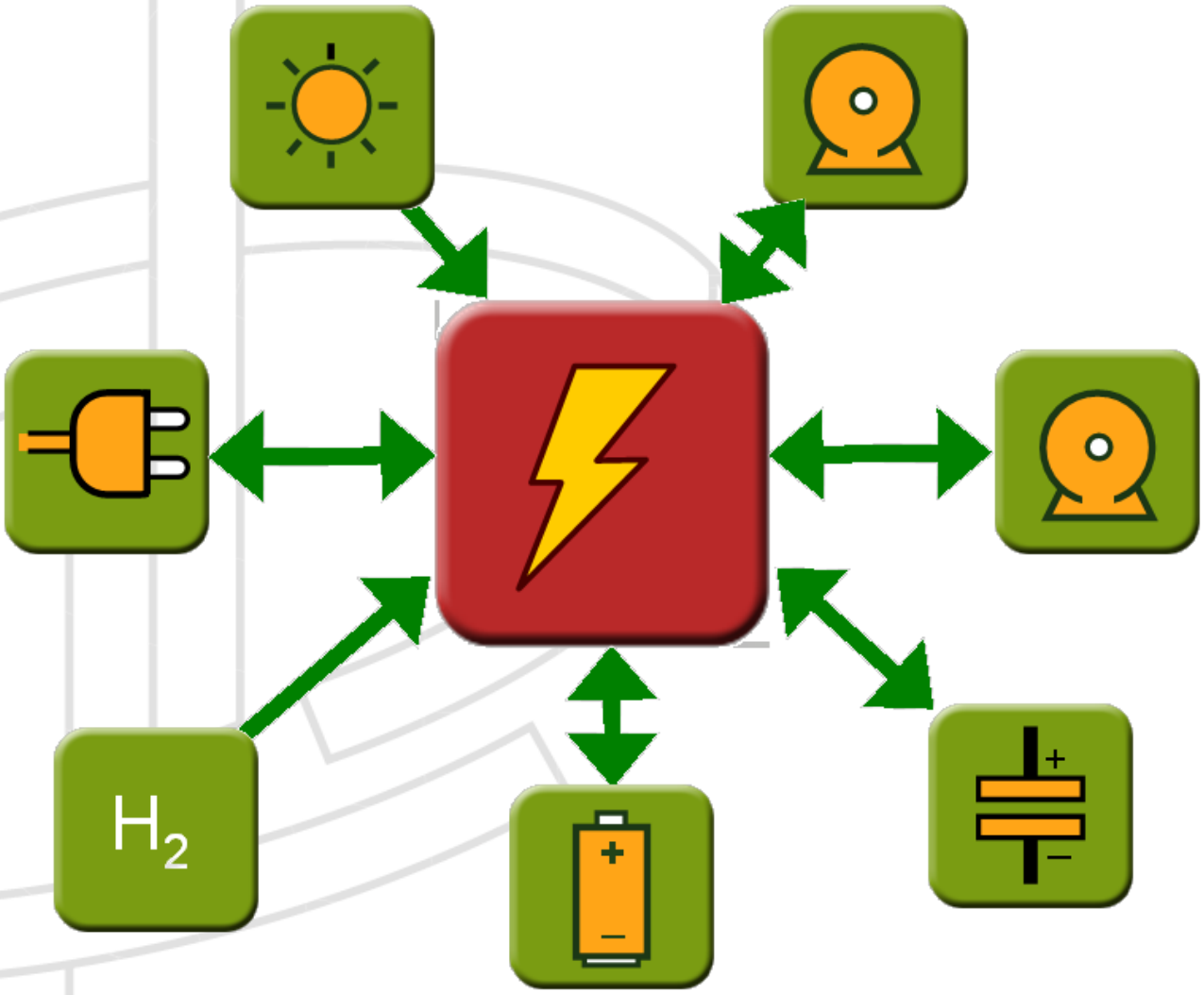
- 了解太陽能電池特性
- 光電實驗模擬
- 歐姆定律與電壓電流量側電錶
- 太陽能特性曲線(Isc, Voc, Im, Vm, Fill Factor)
- 光源密度與陰影
- 充電與換流器的基本電路
- 使用太陽能電池充電
- AC/DC換流器(sine wave/pseudo sine wave)
- 獨立運作12V太陽能發電系統
- 與市電併聯, 提供3W的Inverter
- 整合模組: 300W 風力發電機模組、 Zigee模組、 Zigbee介面監控模組、 Zigbee資料收集器、 RS485通訊介面
- 可透過PC的webserver監控或PDA

電力電子/類比&數位通訊/資訊安全實驗設備與軟體



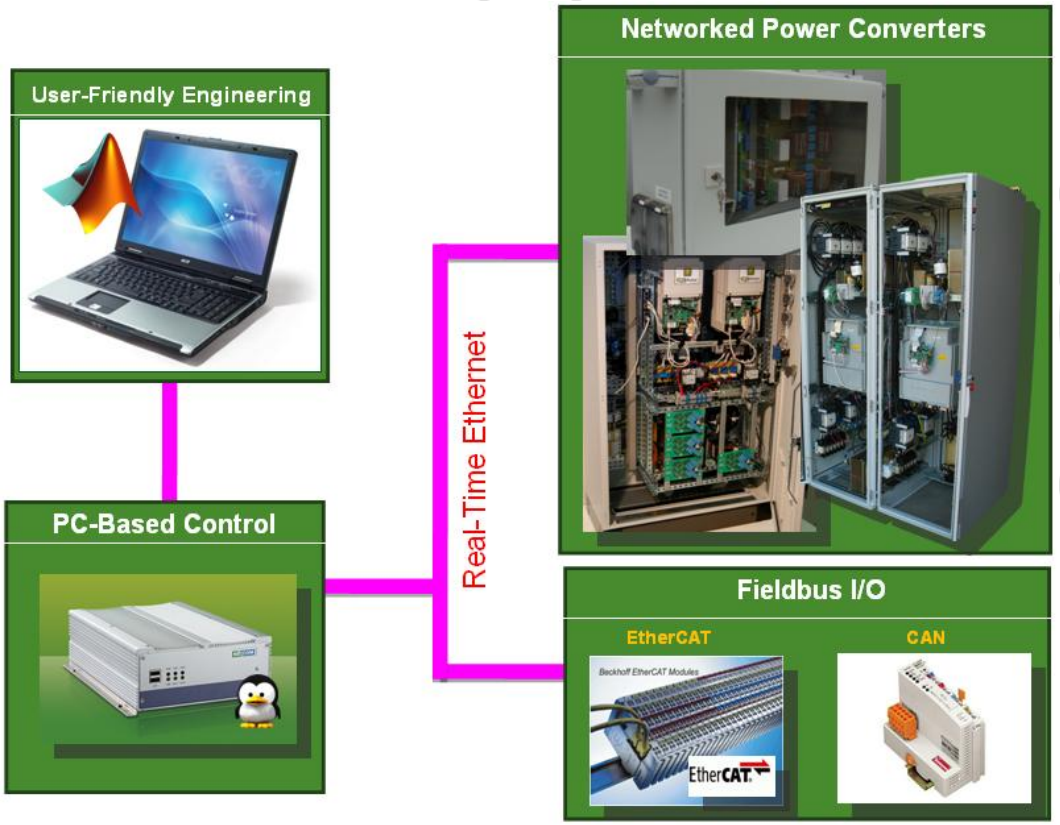


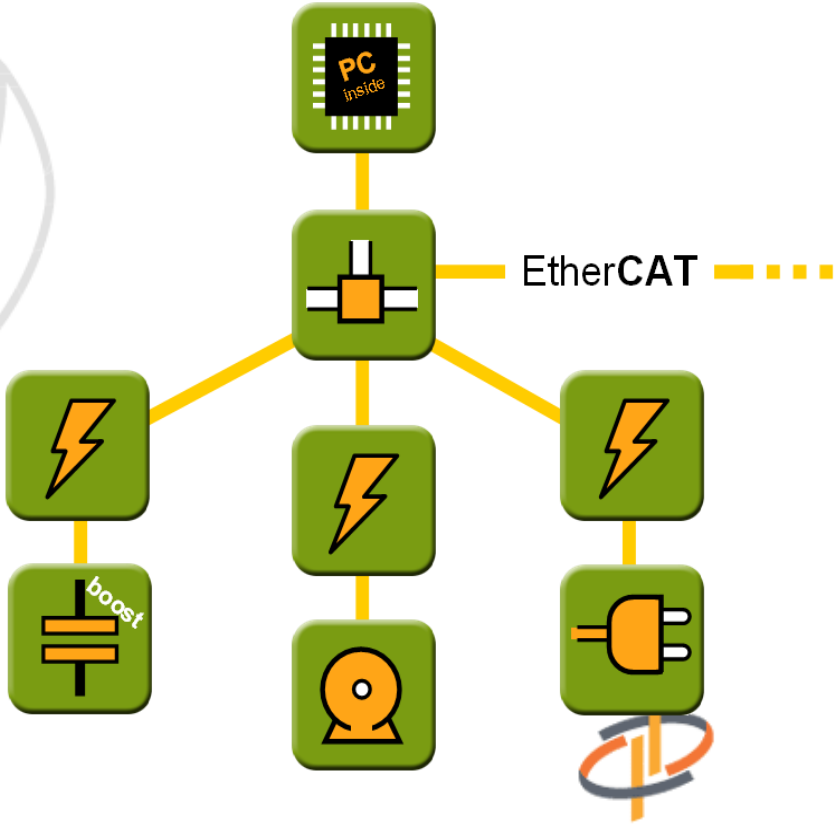
能源管理系統



能源管理系統

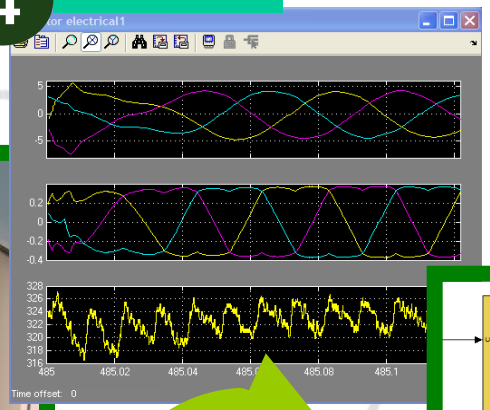
Real-time client/server protocol for inverter control can coexists with EtherCAT fieldbus protocol





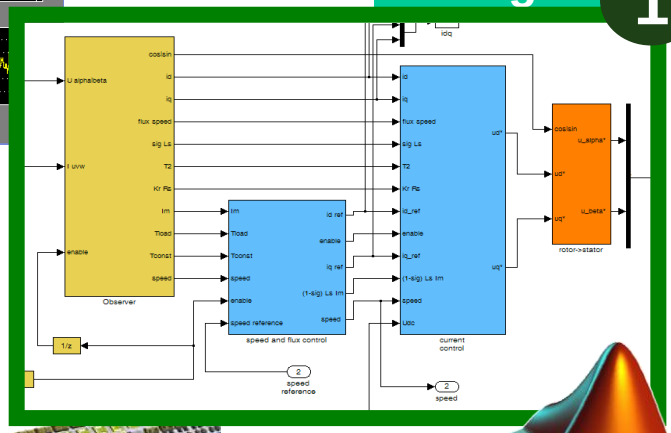
能源管理系統

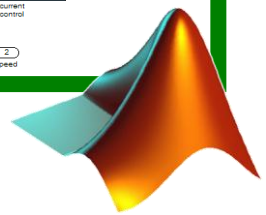
4 monitor



3 test

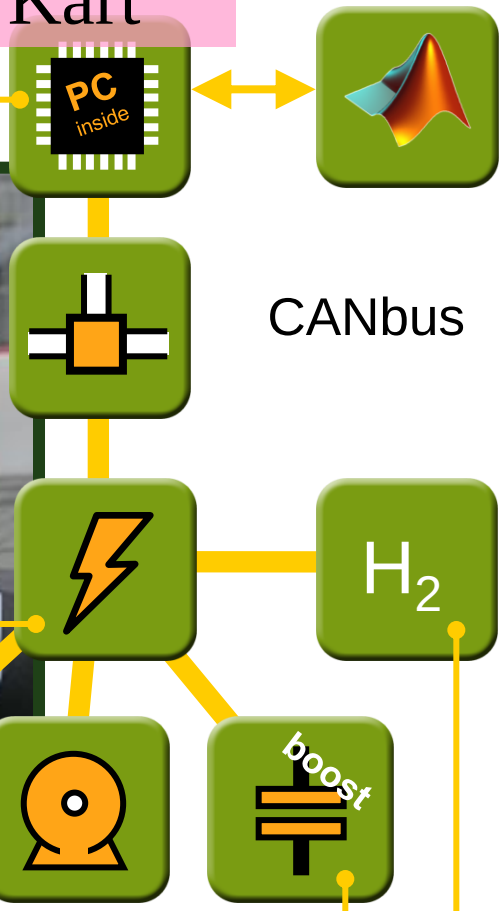
design 1





2 execute

Hydrogen Powered Racing Kart



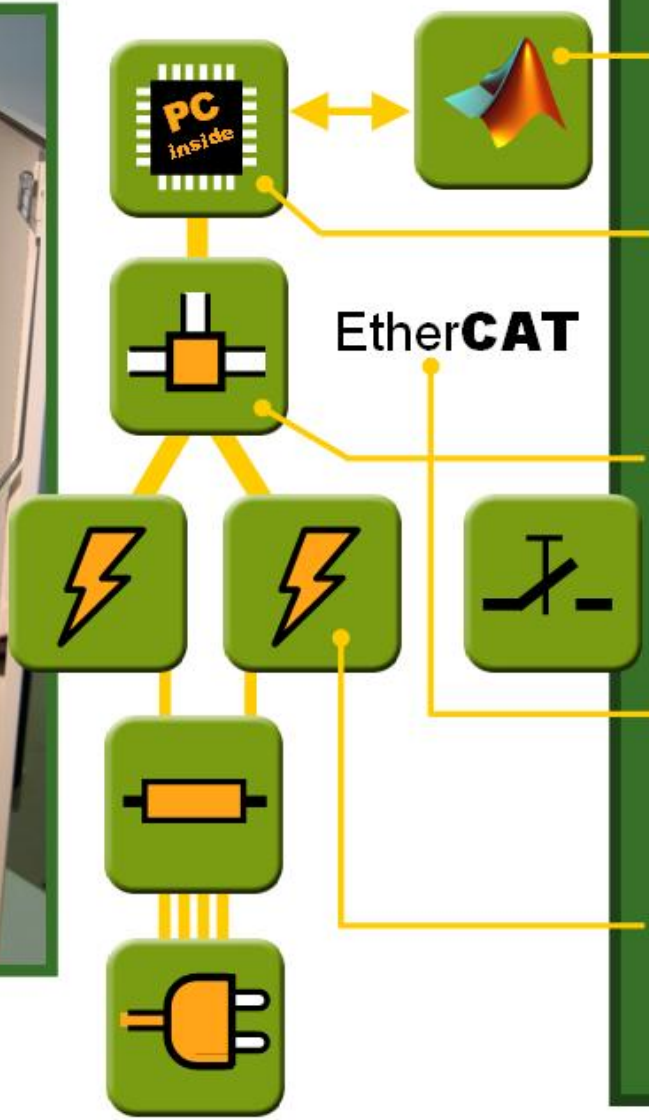
Centralized intelligence ensures optimal control performance

Central converter for optimal coordination of energy flows

Powered by a fuel cell with boostcaps for handling peak power

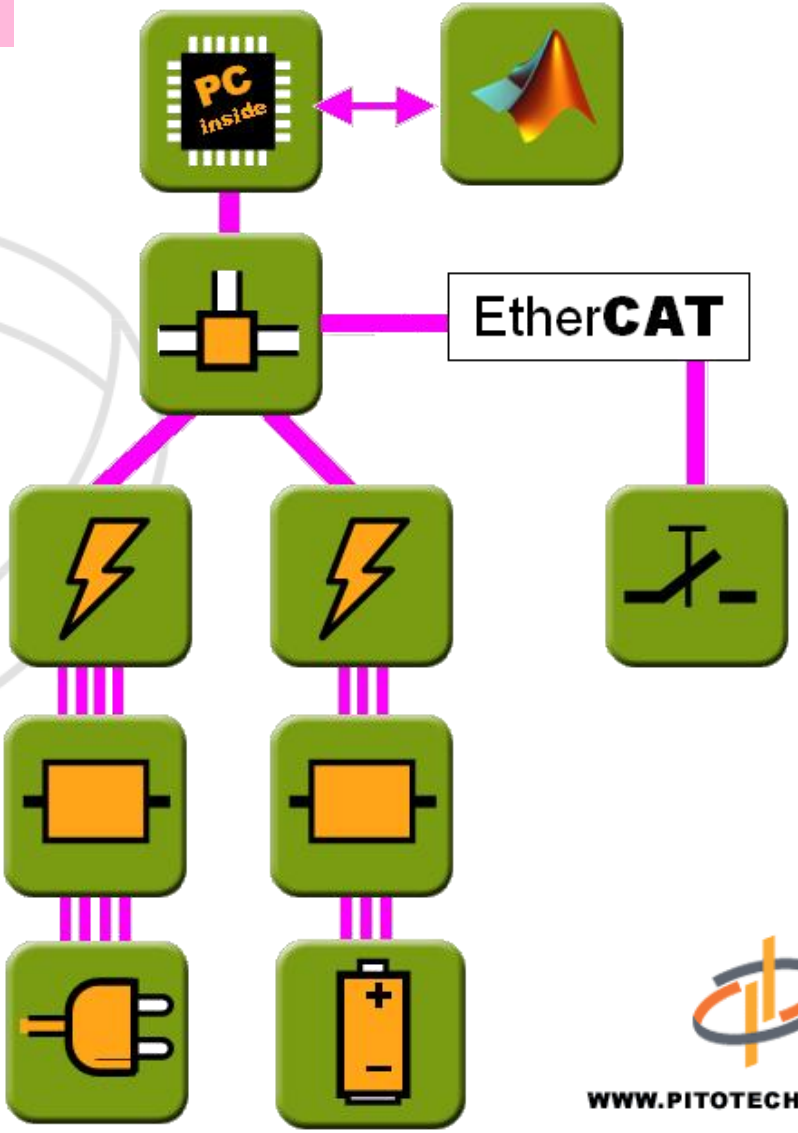
17 kVA Active Frontend

PM10F40C

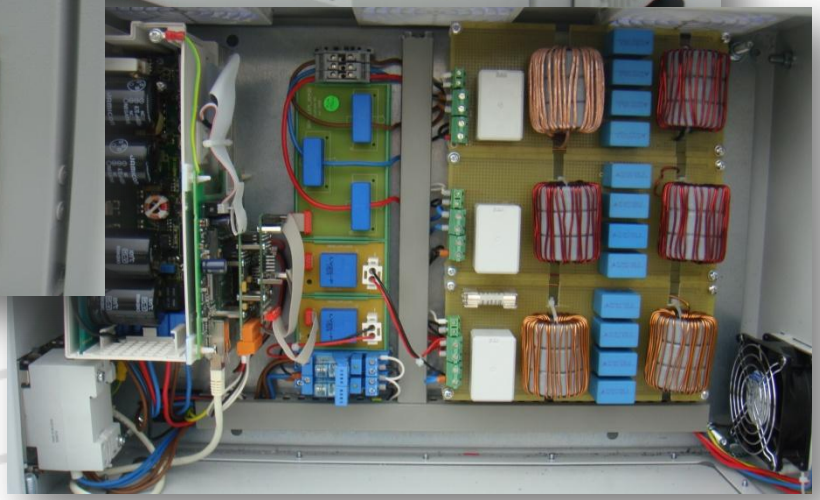


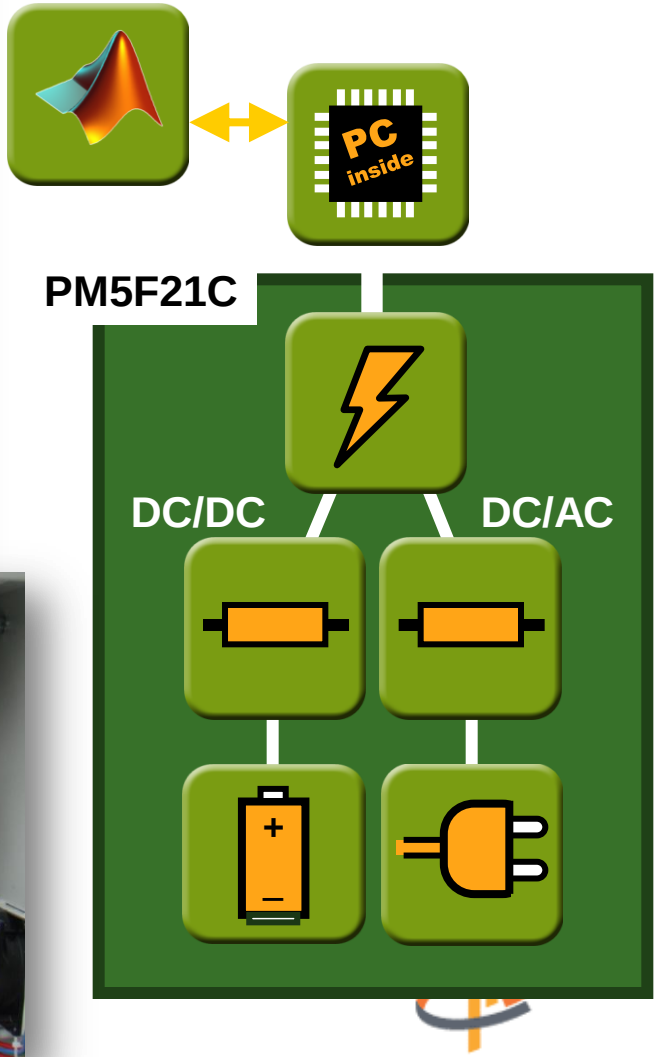
- Software design in Matlab/Simulink™
- Central embedded PC for high-performance control.
- Ethernet for high speed, real-time communication
- EtherCAT fieldbus support for additional I/O
- Modular power stages ranging from 10 to 300 kW.

75 kVA Island Grid



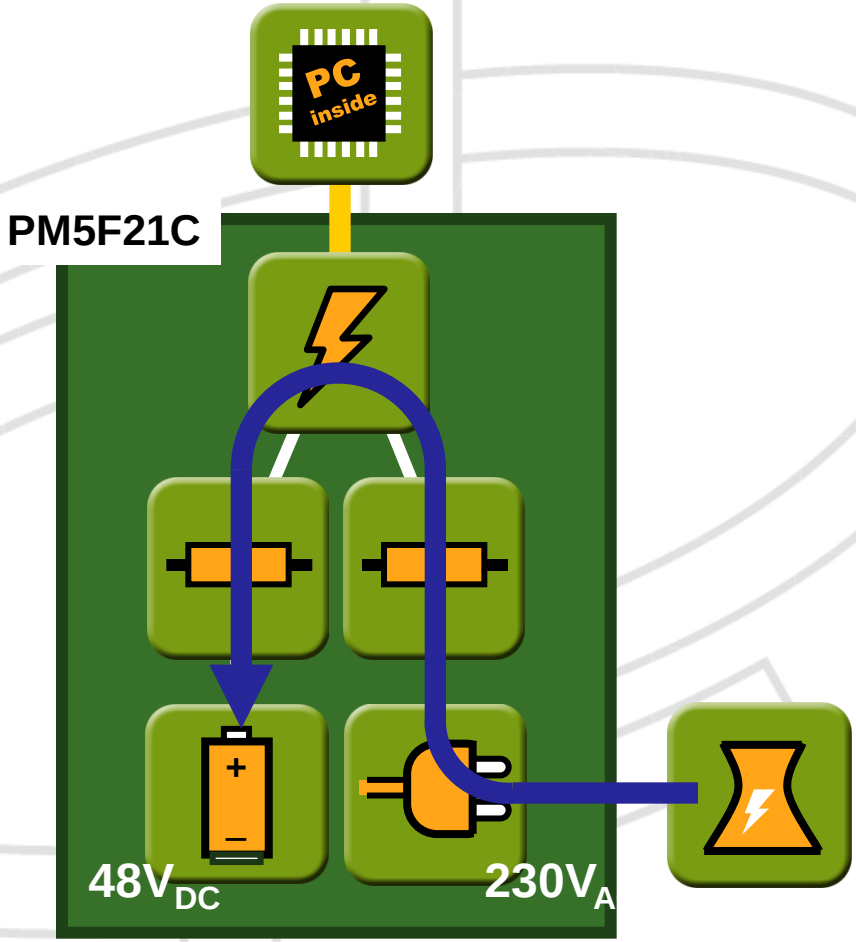
PM5F21C



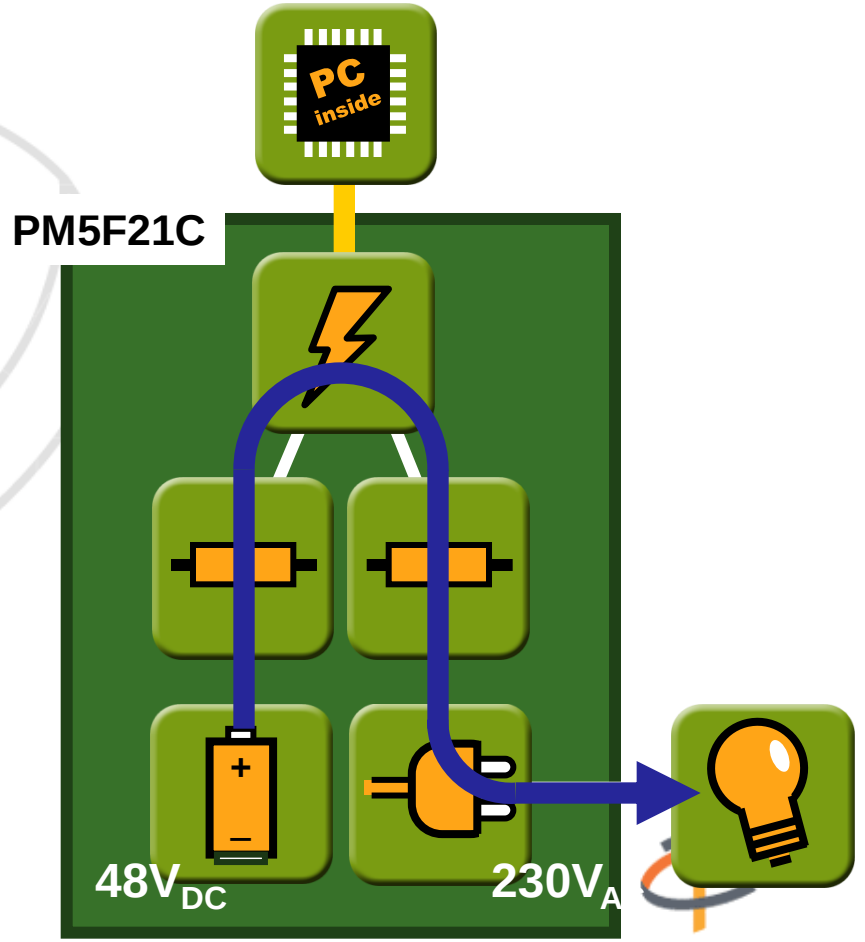


Applications

- Battery Charger

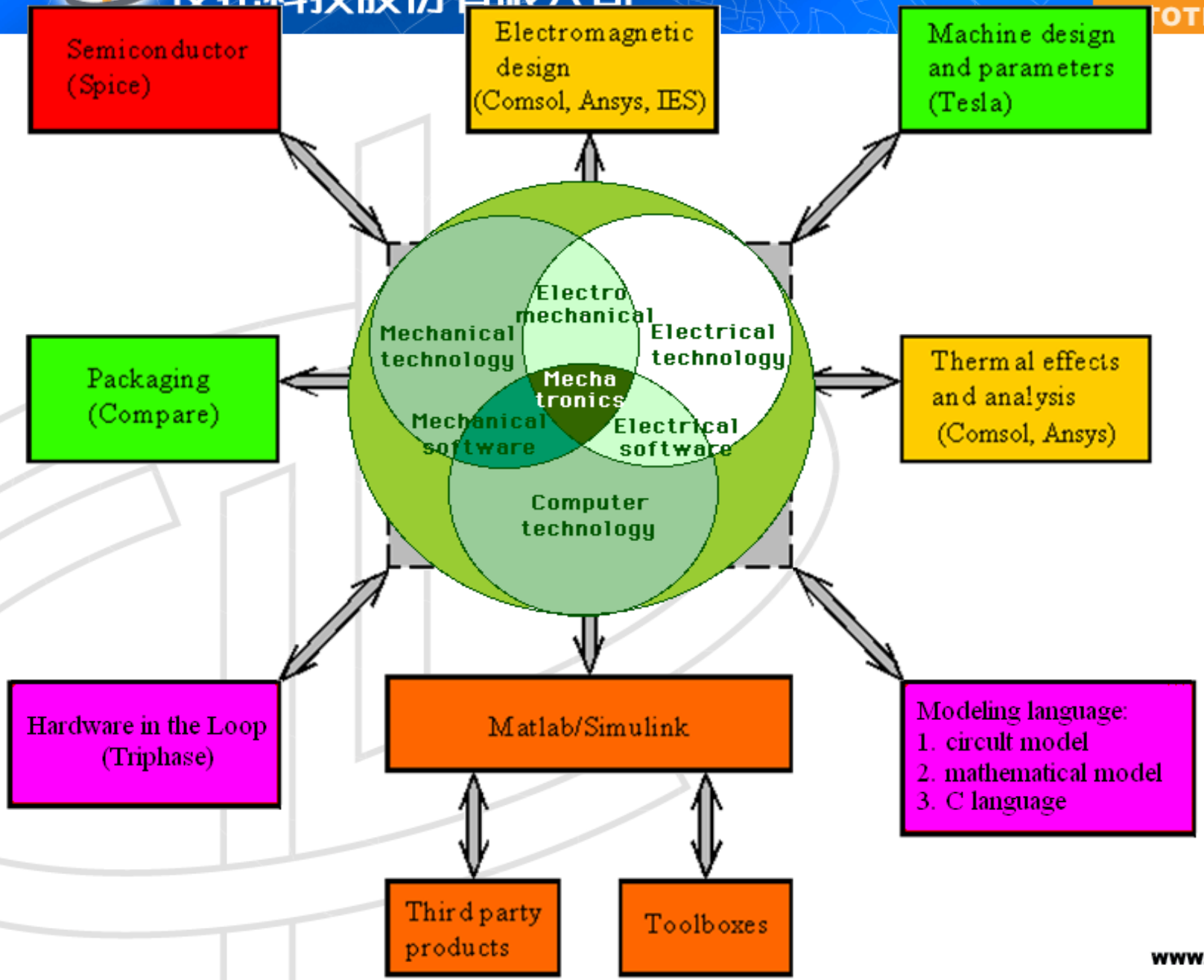


- Local Grid



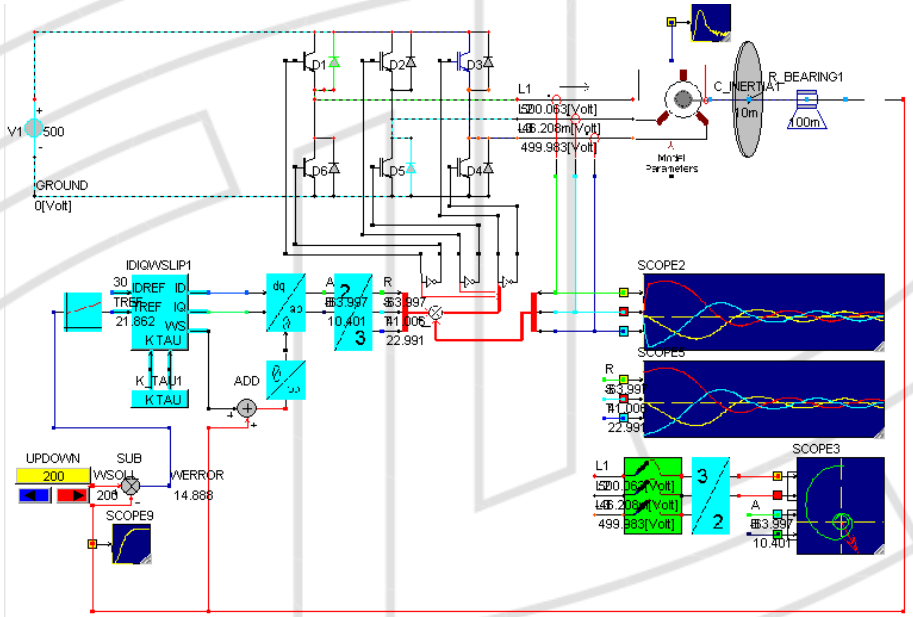
Session II：綠能電力電子系統模擬建置 -使用CASPOC軟體-

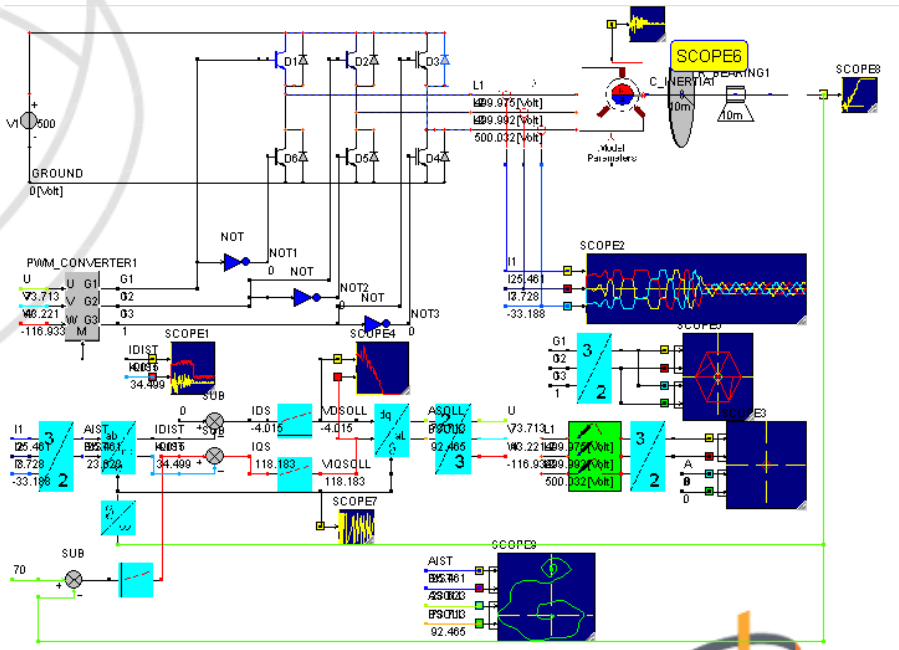
- 使用CASPOC建模(Modeling)與模擬(Simulation)
- 標準太陽能(solar array)與風機模型(turbine model): 基本電路、建模、取樣點
- 數值分析方法(numerical analysis)與實驗設計(multiple simulation)- 改動照度(irradiance)、溫度(temperature)、風速(wind speed)、負載(load)、...等實驗因素的影響
- 與市電併聯(Grid-connection)、換流器(inverter)與控制電路設計


Semiconductor (Spice)
Electromagnetic design (Comsol, Ansys, IES)
Machine design and parameters (Tesla)
Packaging (Compare)
Mechanical technology
Electro mechanical
Electrical technology
Mecha tronics
Mechanical software
Electrical software
Computer technology
Thermal effects and analysis (Comsol, Ansys)
Hardware in the Loop (Triphase)
Matlab/Simulink
Modeling language:
1. circuit model
2. mathematical model
3. C language
Third party products
Toolboxes

Motion Control and Variable Speed Drives

- 馬上可用的元件, 如abcdq transformer, PI-controller, Analog/Digital filter, …
- 包含許多範例, (90個以上電力電子範例, 65個以上電動機驅動)
- 永磁同步機, 感應電動機, 同步機, 發電機, 無刷直流系統, 步進馬達, 汽車(DC與三相), ….





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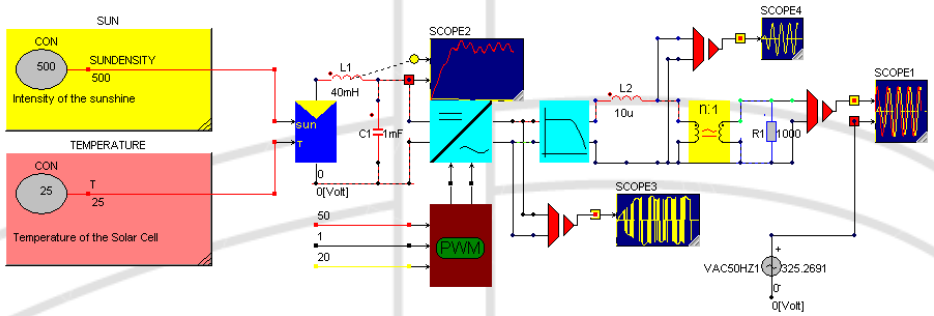
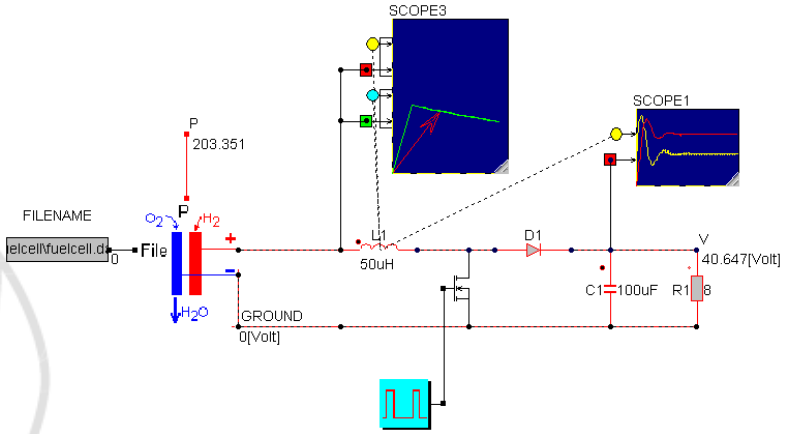
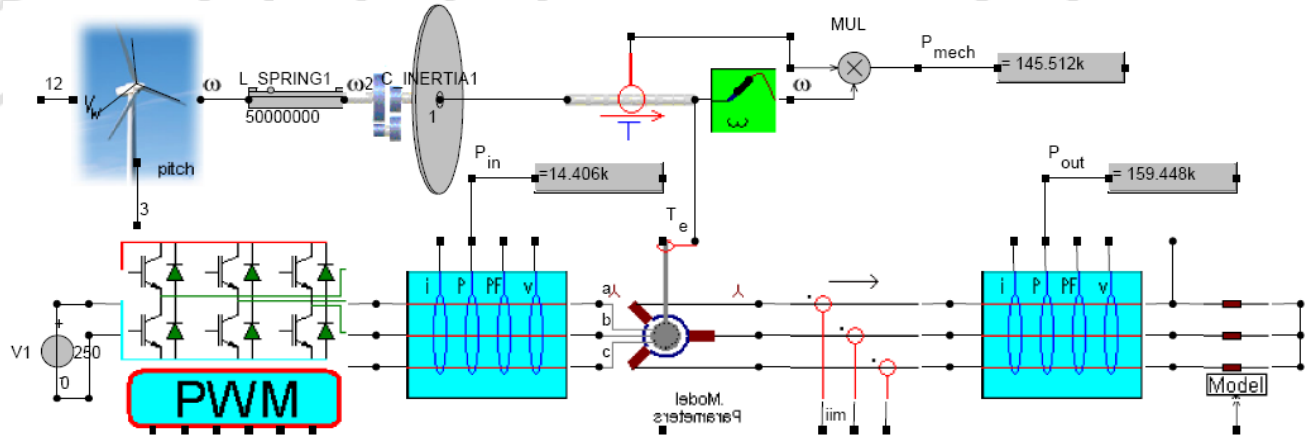
Green Renewable Energy

- 太陽能電池與市電的比較





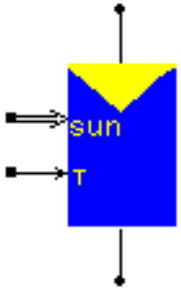
- 風力發電機與雙饋感應發電機(DFIG)

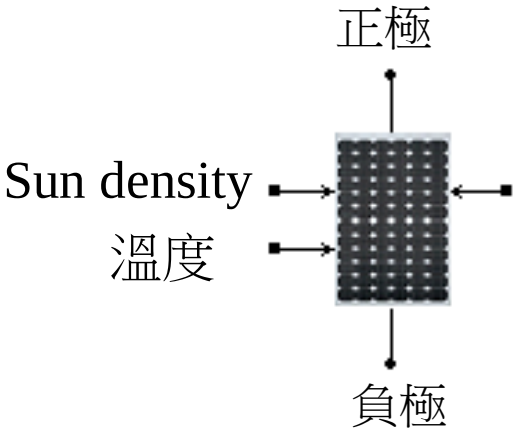


- \Samples\GreenEnergy\Solar\SolarModul_InverterTrafoCompareWithMains.csi
- \Samples\GreenEnergy\FuelCell\fuelcell.csi

太陽能電池模擬

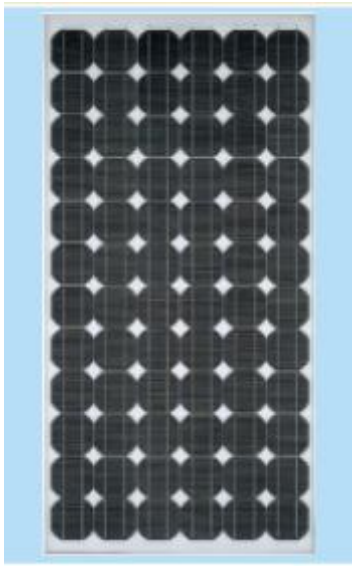
- 太陽能電池模型
  - 光譜與玻璃材料
  - Irradiance
  - 短路電流
  - 開路電壓
  - 暗電流
  - 完整太陽能模型
  - 與溫度相關
- 系統模擬
  - 太陽能板可連接到負載
  - 太陽能板可連接到inverter
  - 與電力電子系統的結合
  - 與市電結合
  - 模擬太陽能板的I-V特性曲線



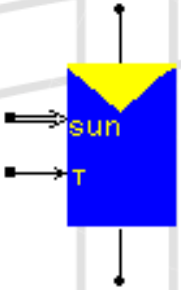


太陽能電池模擬

- 太陽能電池模型
  - Shell SP150 Solar Module
    - 72 Solar cells in series
    - Each cell is 125mm * 125 mm
  - Electrical Characteristic (STC: 1000w/m2, AM1.5, 25˚C)
    - Nominal Voltage 24 [V]
    - Maximum power rating MPP 150[W]
    - Rated current IMPP 4.4 [A]
    - Rated voltage VMPP 34.0 [V]
    - Short circuit current ISC 4.8 [A]
    - Open circuit voltage VOC 43.4 [V]
    - Temp. coefficient of the short-circuit current +2.06 mA / ˚C
    - Temperature coefficient of the open-circuit voltage -0.152 V / ˚C

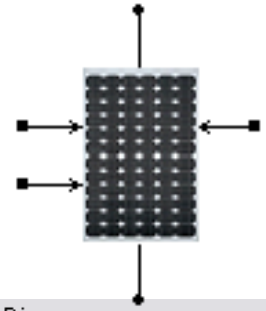


太陽能電池模擬



Parameters Block Diagram

Imax@1000W/m2	4.8
Imax@Vmpp@1000W/m2	4.75
Ti	2m
Tn	25
Tv	-0.152
Vmpp	34
Voc	43.4



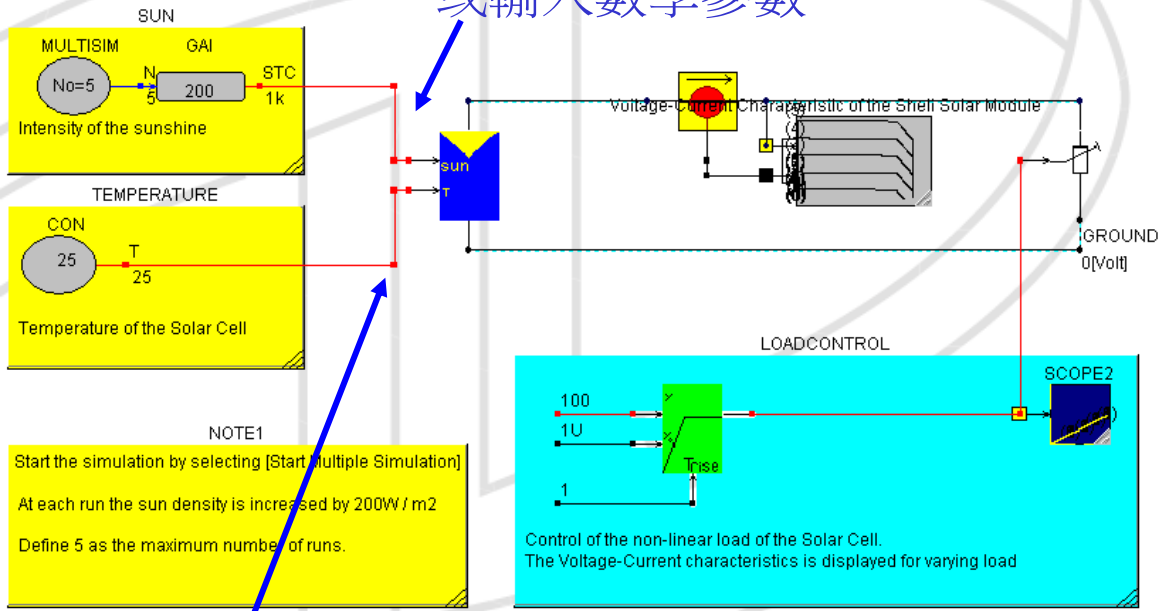
Parameters Block Diagram

Cparallel	1nF
Enom[W/mm2]	1000
Factor[10_100]	10
Impp[A]	4.4
Isc[A]	4.8
Lseries[H]	1n
Rparallel[Ohm]	100
Rseries[Ohm]	20m
Tn[C]	25
Umpp[V]	34
Uoc[V]	43.4
alphaI[A/Celcius]	2.06m
alphaU[V/Celcius]	-0.152

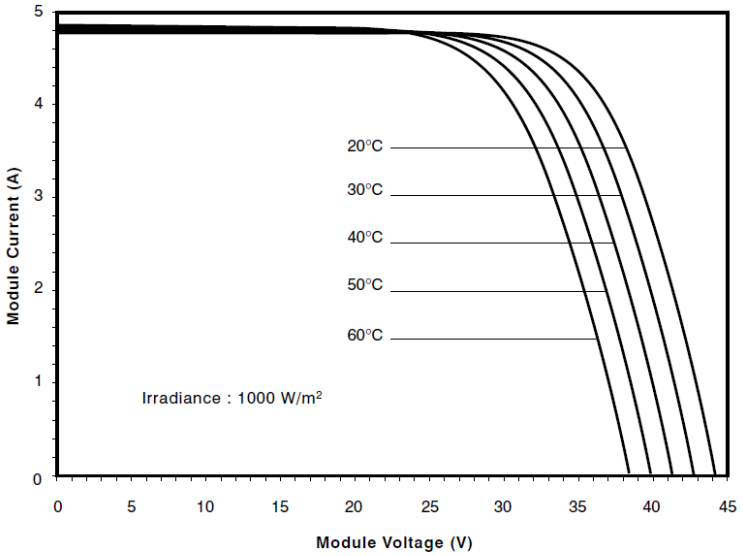
太陽能電池模擬

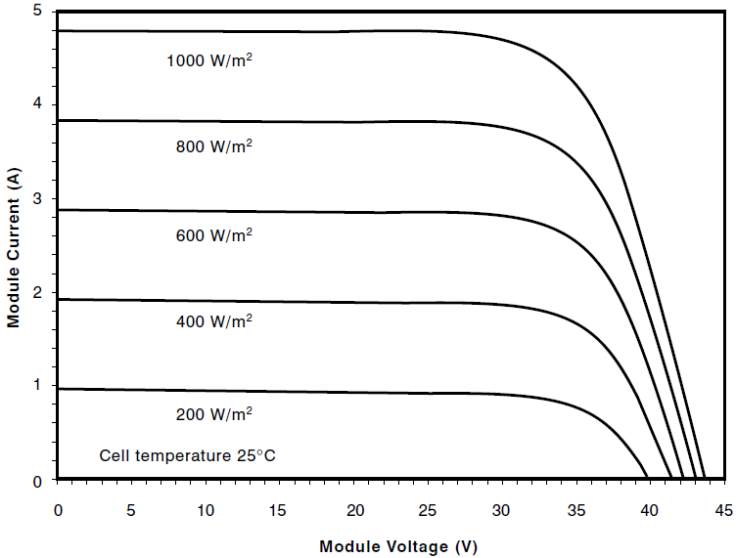
- I-V特徵曲線受到輻照度與溫度的影響

輻照度可由外部讀表,
或輸入數學參數

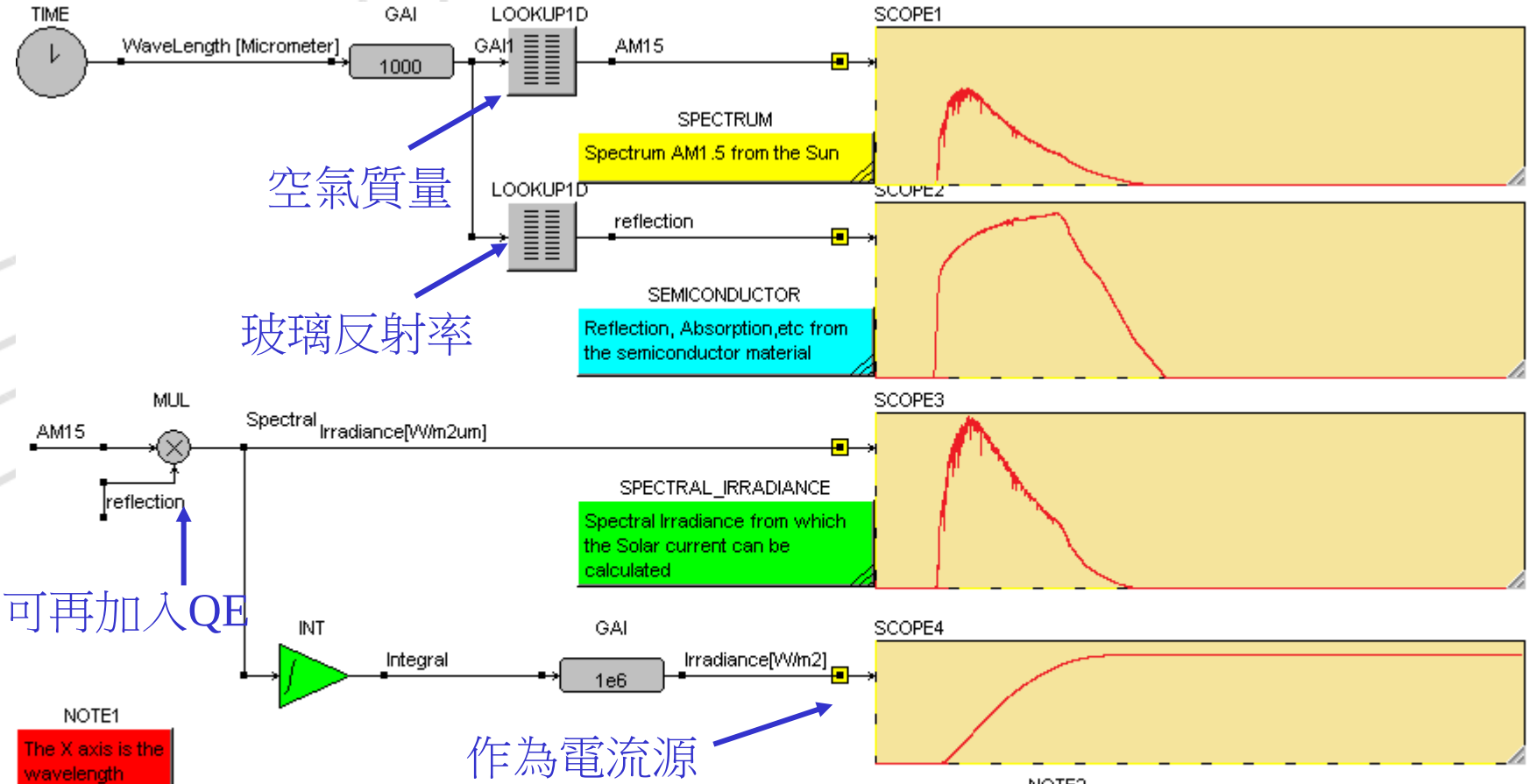


溫度亦可讀表或調整
輸入數學參數



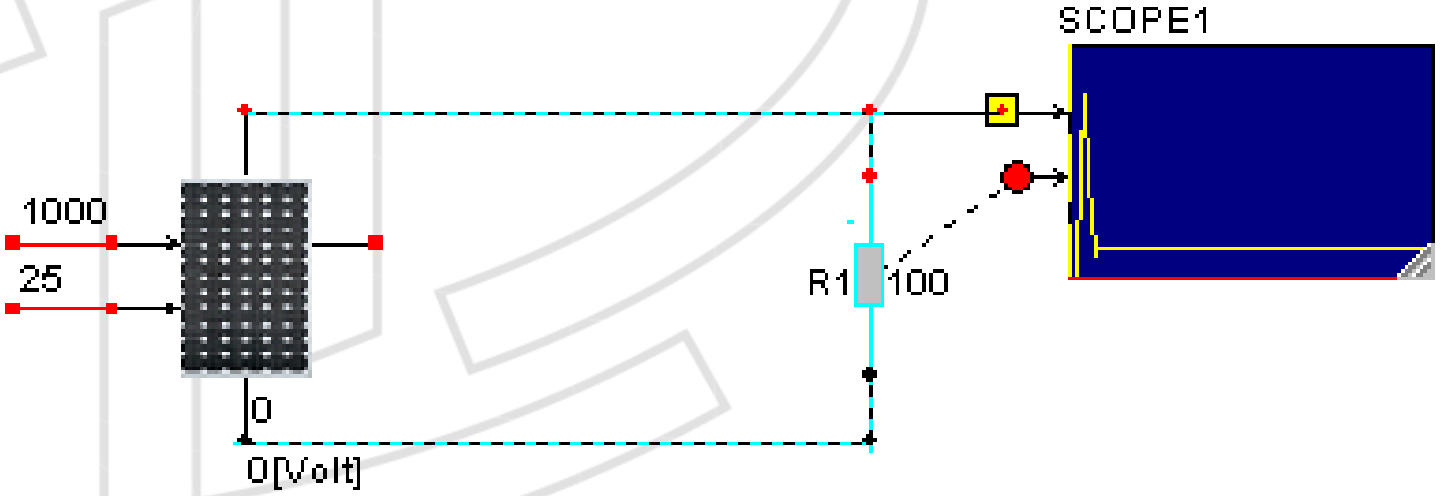


太陽能電池模擬


TIME
WaveLength [Micrometer]
GAI
1000
LOOKUP1D
GAI1
AM15
SCOPE1
SPECTRUM
Spectrum AM1.5 from the Sun
空氣質量
LOOKUP1D
reflection
SCOPE2
SEMICONDUCTOR
Reflection, Absorption,etc from the semiconductor material
玻璃反射率
MUL
AM15
Spectral Irradiance[W/m2um]
SCOPE3
reflection
SPECTRAL_IRRADIANCE
Spectral Irradiance from which the Solar current can be calculated
可再加入QE
INT
Integral
GAI
1e6
Irradiance[W/m2]
SCOPE4
作為電流源
NOTE1
The X axis is the wavelength scale in [micrometer] for all scopes
NOTE2
The intregral over the Spectral Irradiance gives the solar current in Watt per square meter. This value is used in the solar cell simulation for the current source.
The end value in the scope is the photon current (Irradiance) This value is taken nummerically and used for the solar cell current source

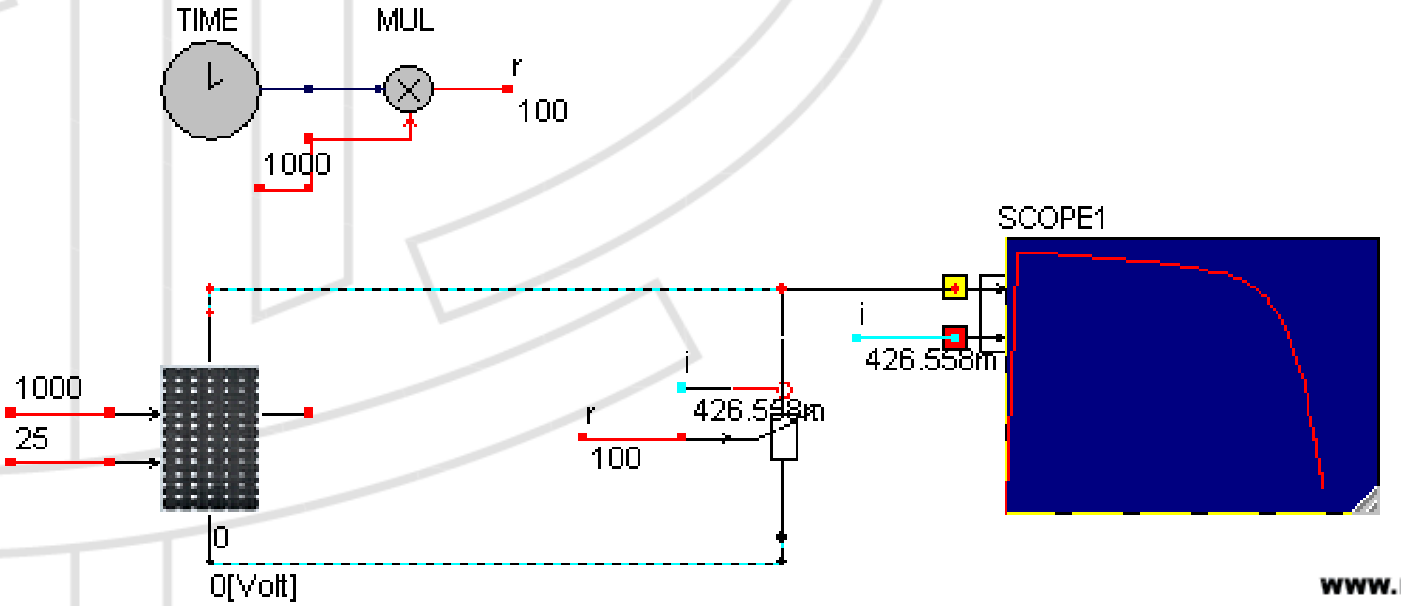
太陽能電池模擬

- 模型建立 – 1：
- Circuit > RLC > R
- Library > GreenEnergy > SolarmoduleSemi



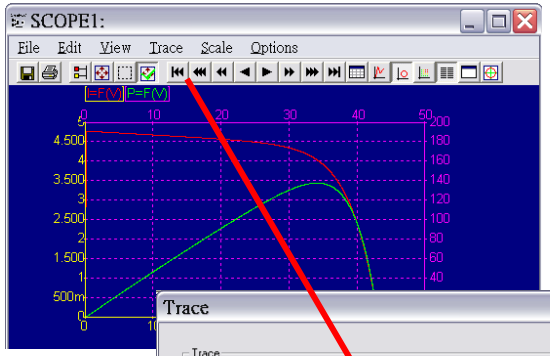
太陽能電池模擬

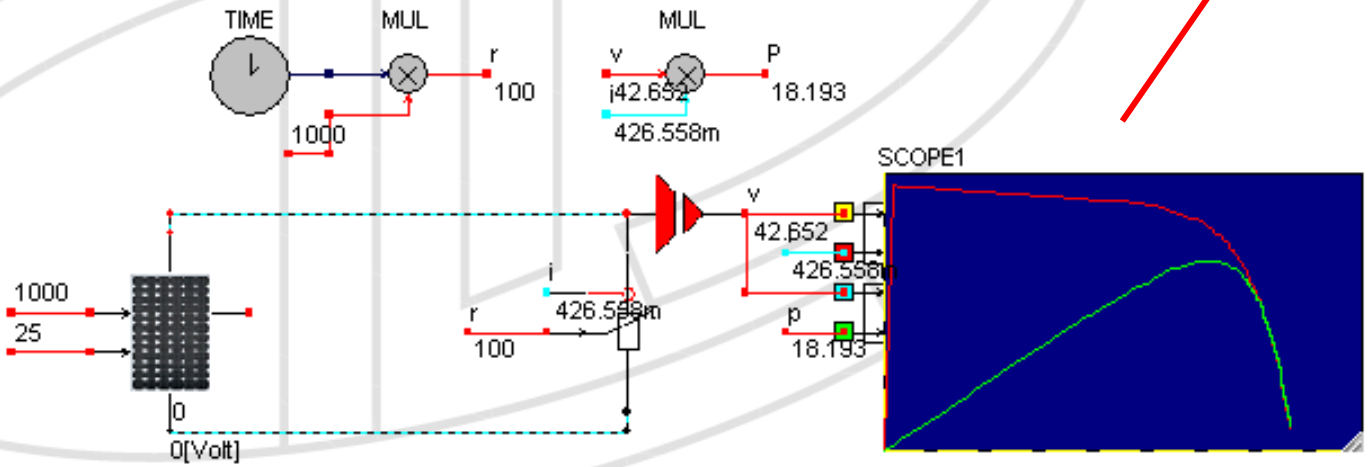
- 模型建立 – 2：
- Library > Electric > R > R_I
- Library > GreenEnergy > SolarmoduleSemi
- Blocks > Source > Time
- Blocks > Math > Mul



太陽能電池模擬

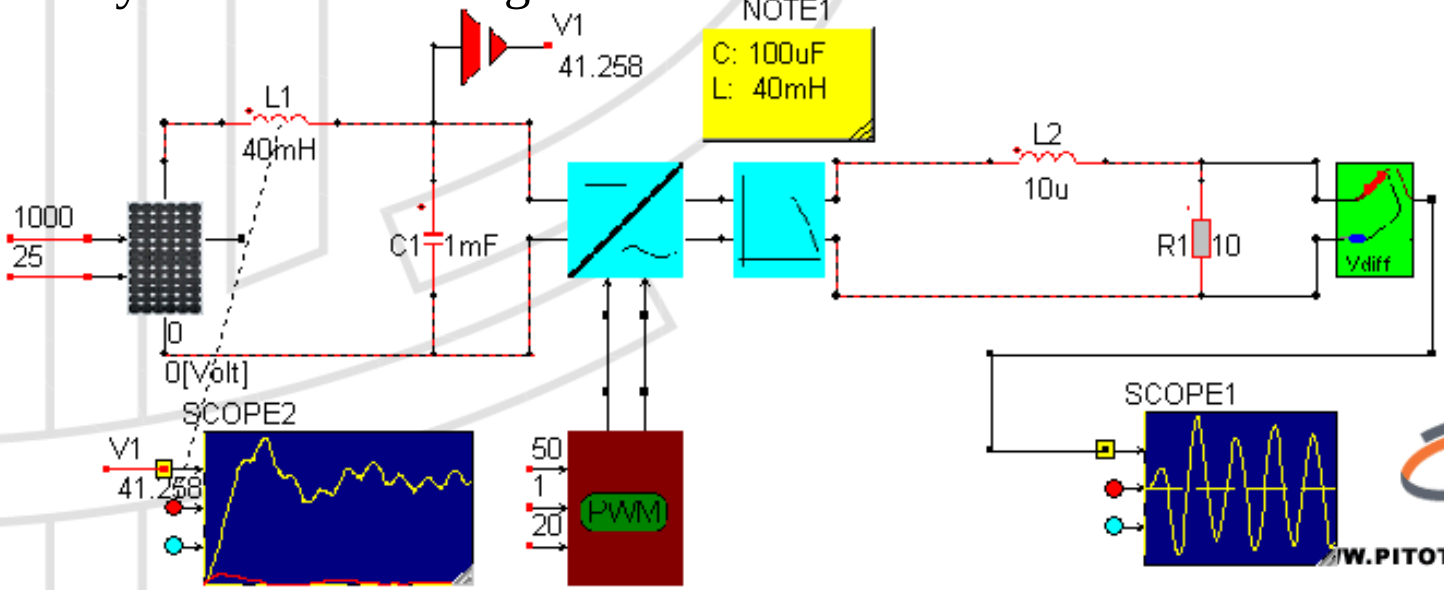
- 模型建立 – 3：
- Library > Sensor > Voltage > v
- 使用MUL計算功率(P=V*I)
- 設定SCOPE1 > Trace > Trace4 > Scale Right





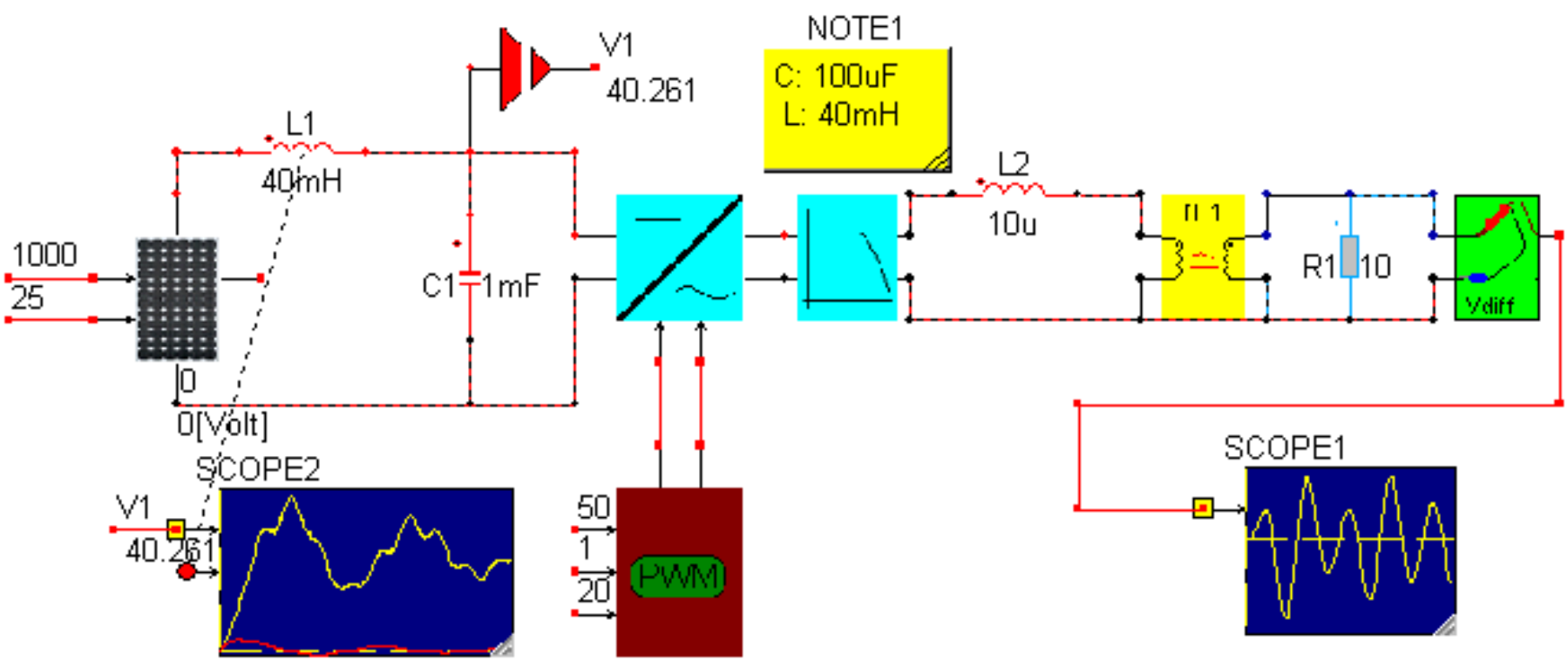
太陽能電池模擬

- 模型建立 – 4：與Inverter結合
- Library > GreenEnergy > SolarmoduleSemi
- Circuit > RLC > L ,C , and R
- Library > PowerConverters > Inverters2phase > pwm2 and vsi2p
- Library > Filters > Circuit > SinglePhase > LowPass
- Library > Probe > vp2
- Library > Sensor >Voltage > v



太陽能電池模擬

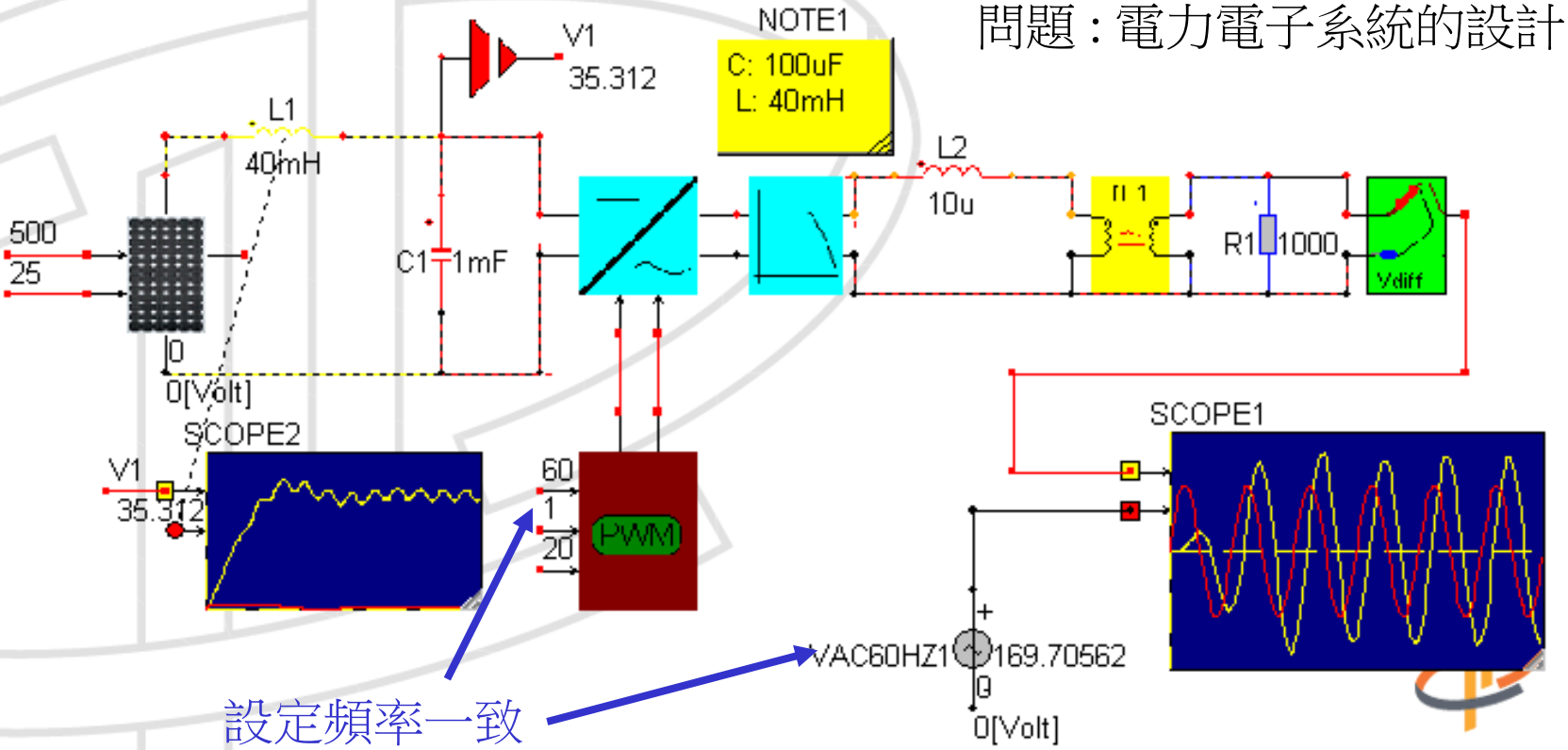
- 模型建立 – 5：加上transformer改變電壓
- Library > Transformers > Ideal > Tideal



太陽能電池模擬

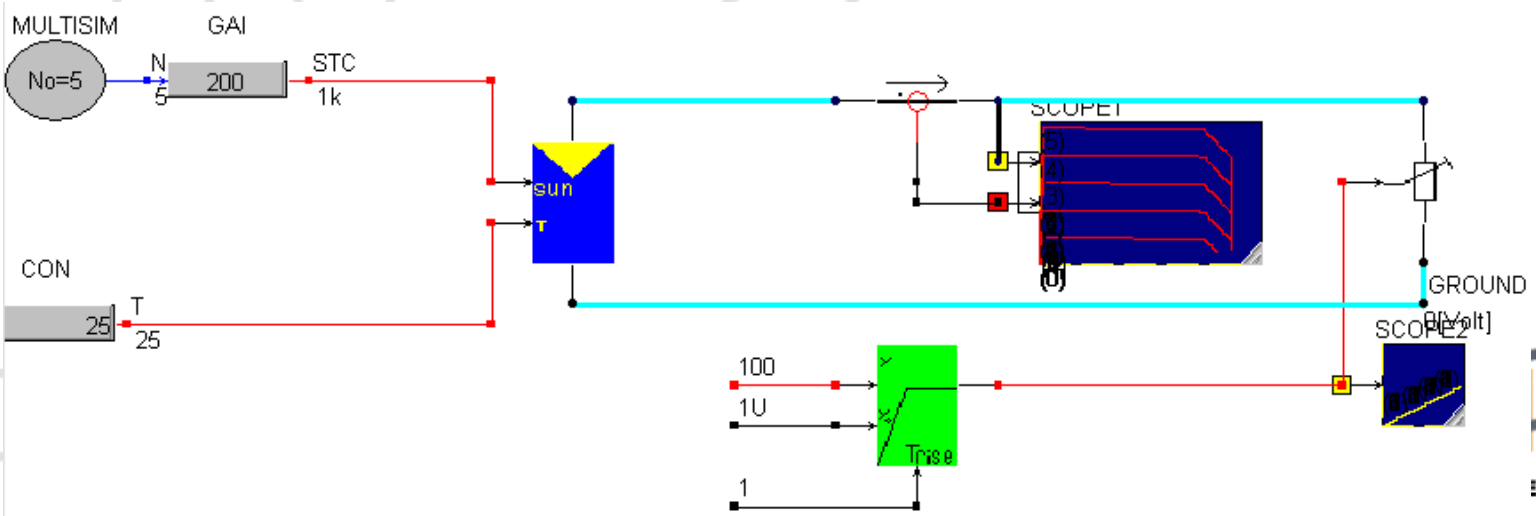
- 模型建立 – 6：與市電比較
- Circuit > Sources > VAC60Hz

- 太陽能電池為一電流源
- 與市電並連需解決相位延遲問題：電力電子系統的設計



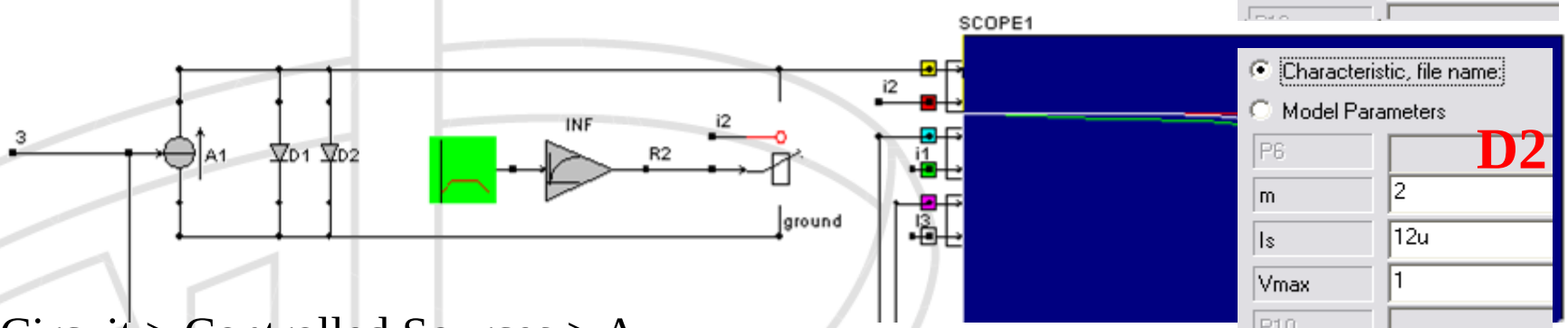
太陽能電池模擬

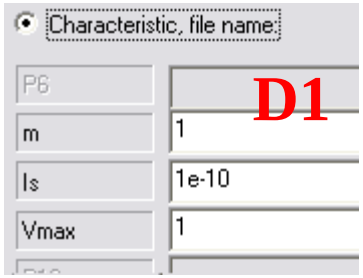
- 模型建立 – 7: 不同照度與不同溫度下,太陽能電池的特徵曲線變化
- Library > GreenEnergy > Solar > SolarModul
- Library > Electric > R > R
- Library > Control > Sources > Decrease
- Library > Sensor > Current > i
- Blocks > Source > Multisim & CON
- Blocks > Math > GAI



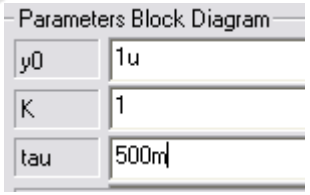
太陽能電池模擬

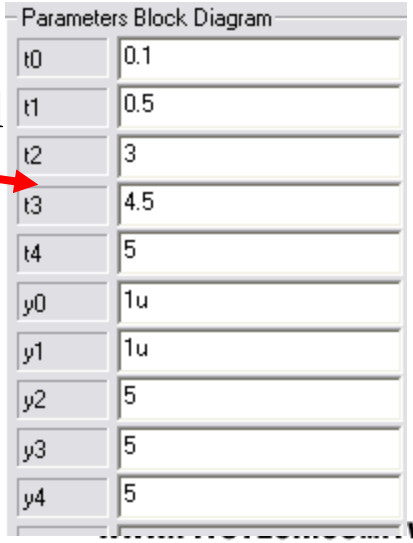
- 模型建立 – 8：基本的Solar Cell模型





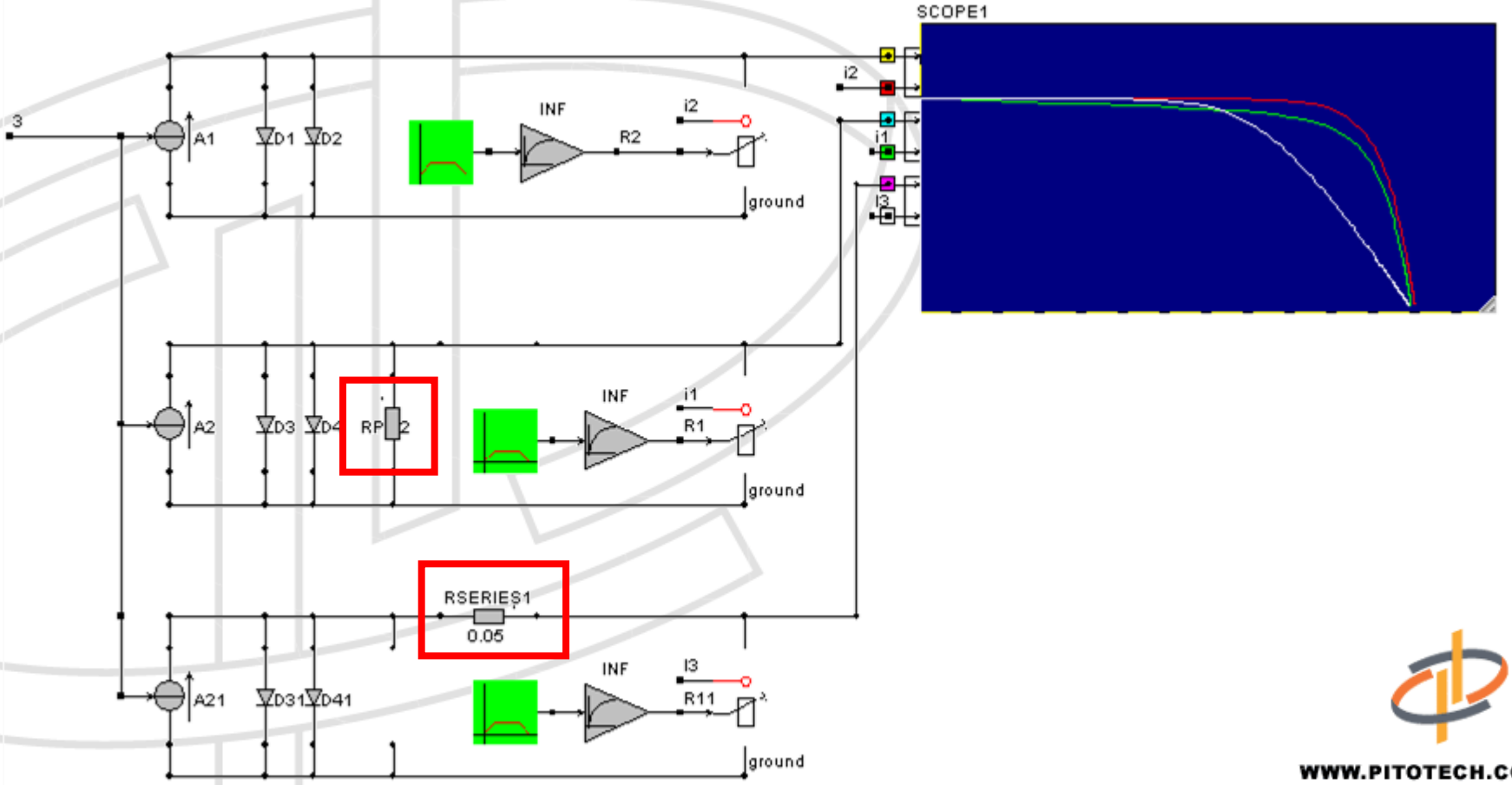
- Circuit > Controlled Sources > A
- Circuit > Semiconductors > D
- Library > Control > Sources> ProgrammableSourceInterpolated
- Blocks > Integrator > INF
- Library > Electric > R > R_I





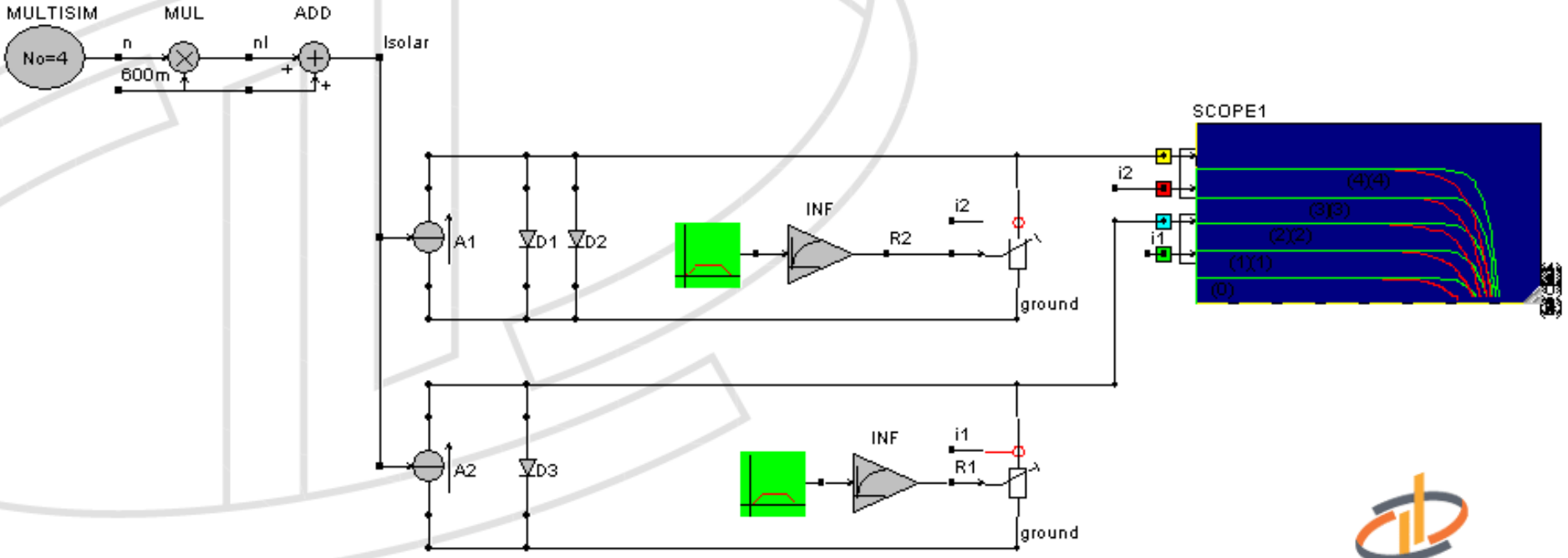
太陽能電池模擬

- 模型建立－9：比較串聯電阻與並聯電組



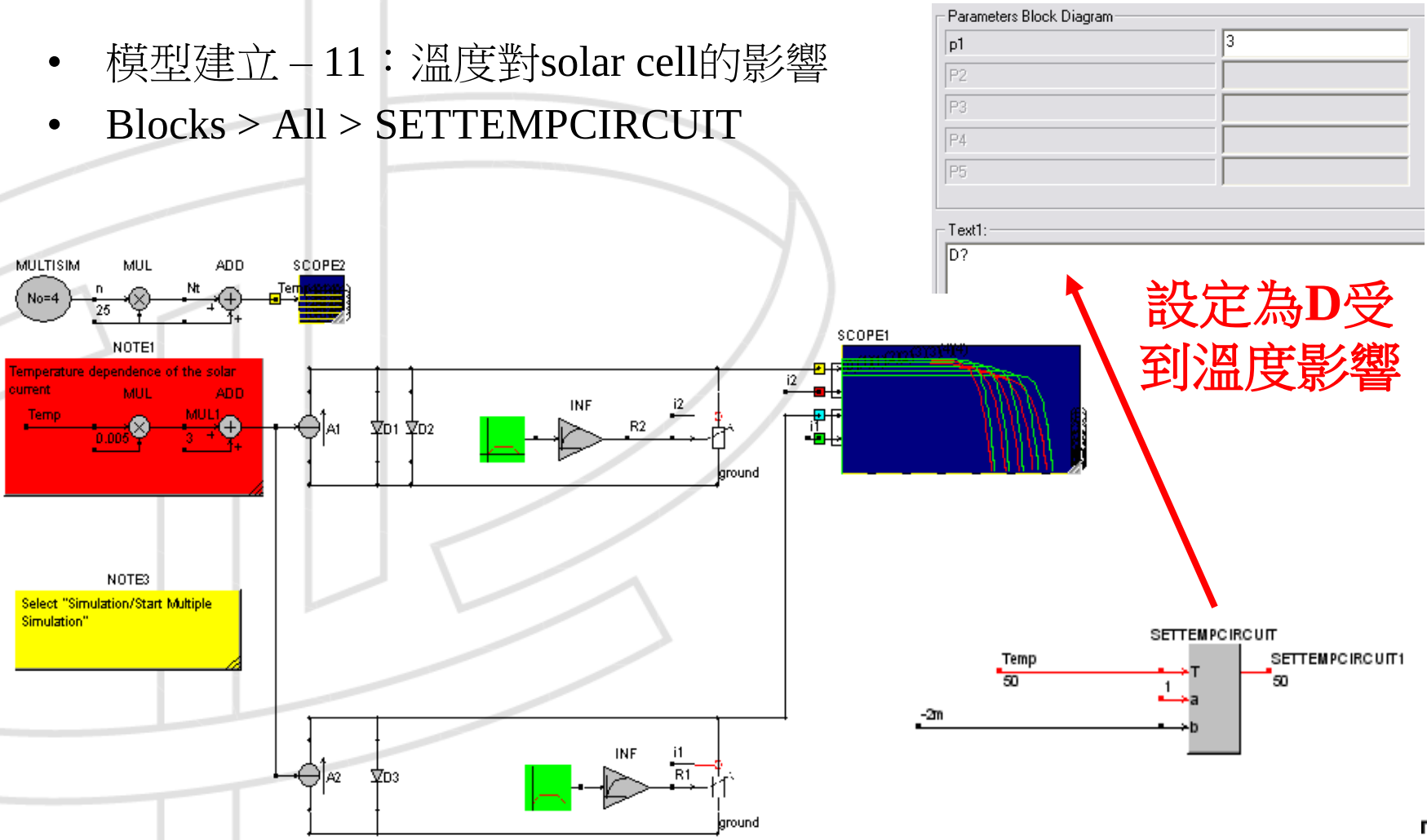
太陽能電池模擬

- 模型建立 – 10：比較照度變化的影響
- Blocks > Source > Multisim
- Blocks > Math > ADD & MUL



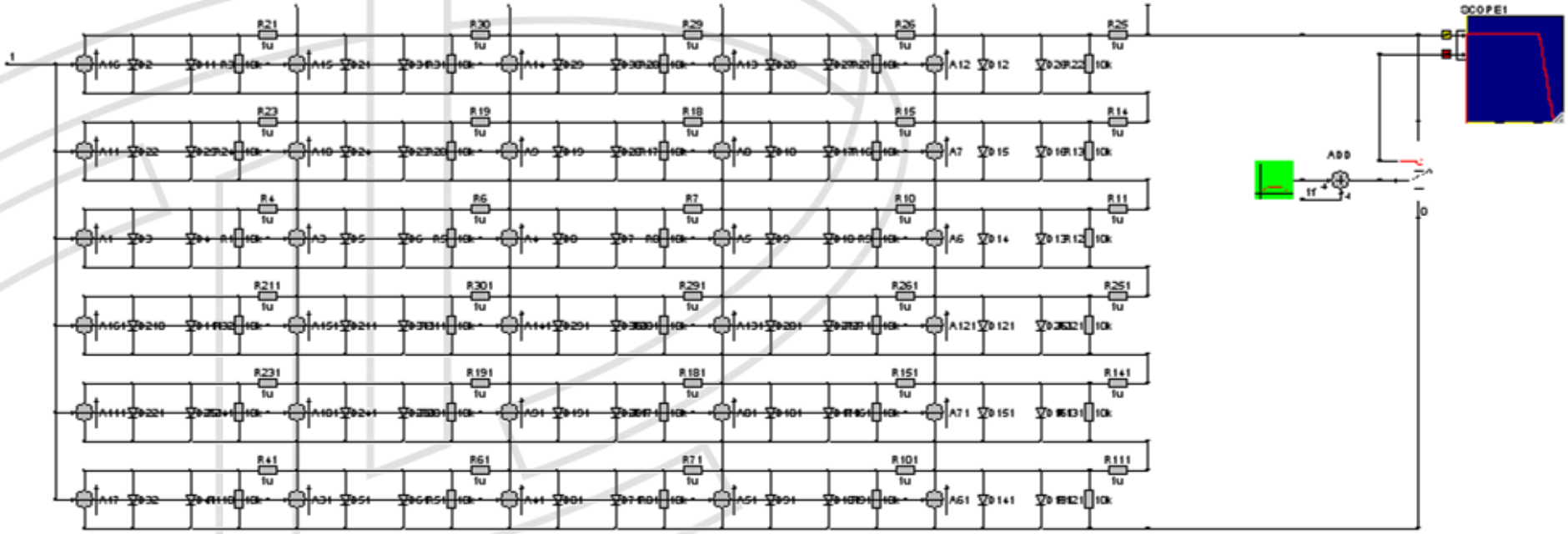
太陽能電池模擬

- 模型建立 – 11：溫度對solar cell的影響
- Blocks > All > SETTEMPCIRCUIT



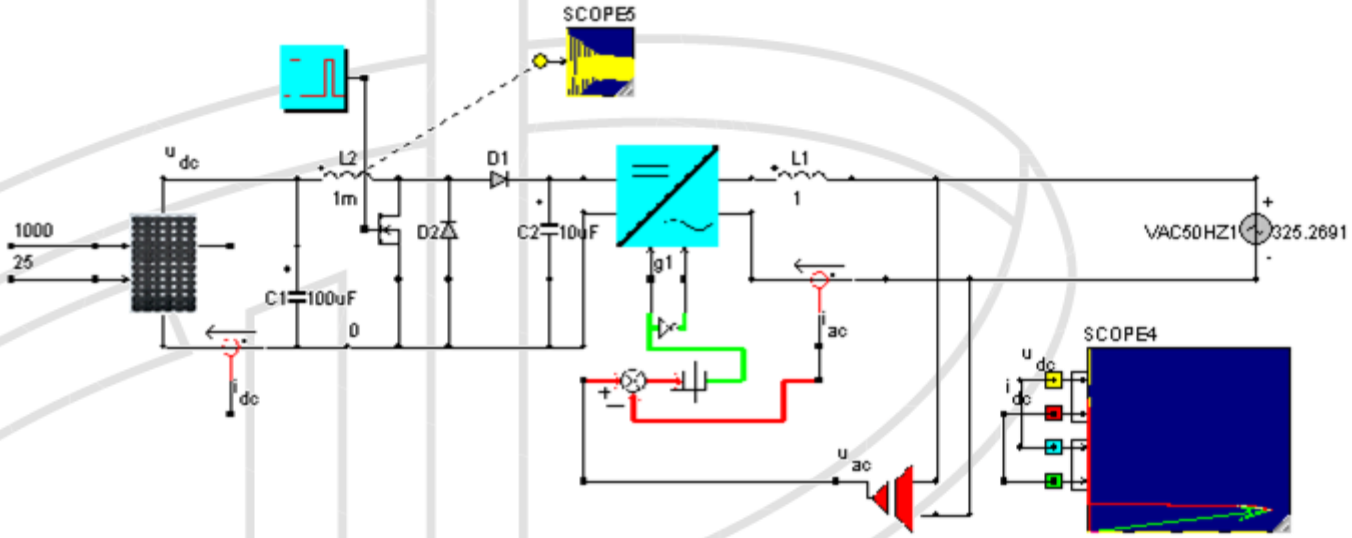
太陽能電池模擬

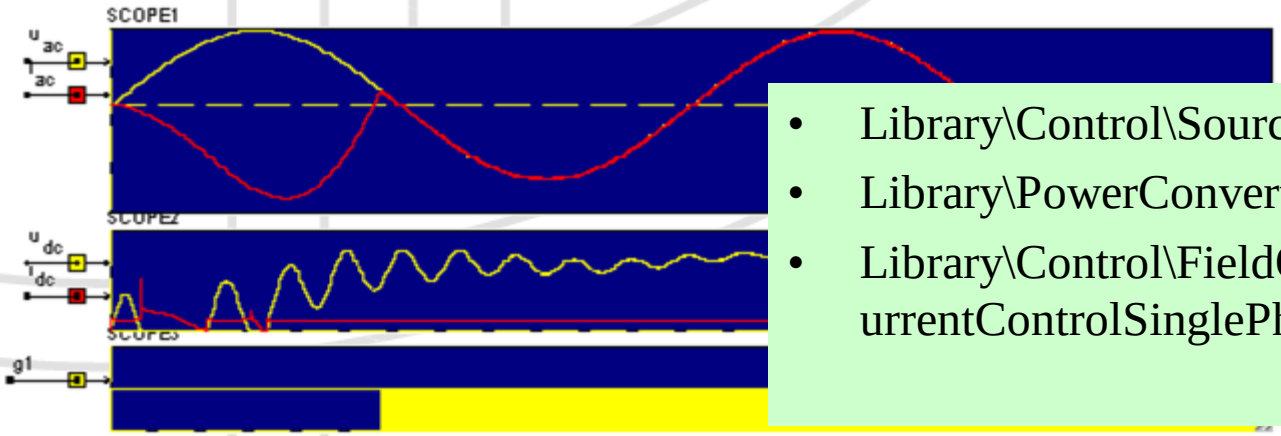
- 模型建立 – 12: 串並聯多個solar cell

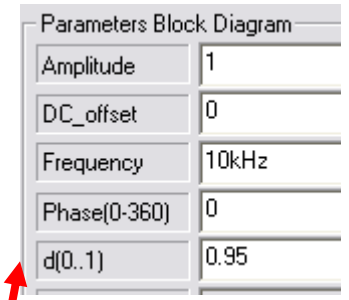


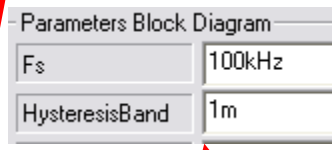
太陽能電池模擬

- 模型建立 – 13：透過Vac與Iac值控制電流導通(gate)



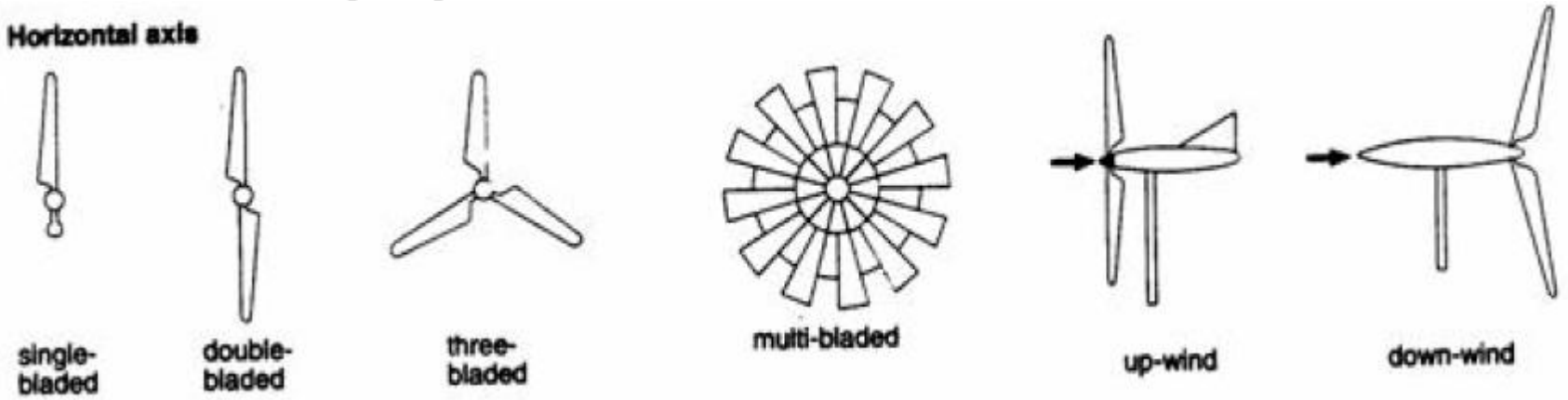


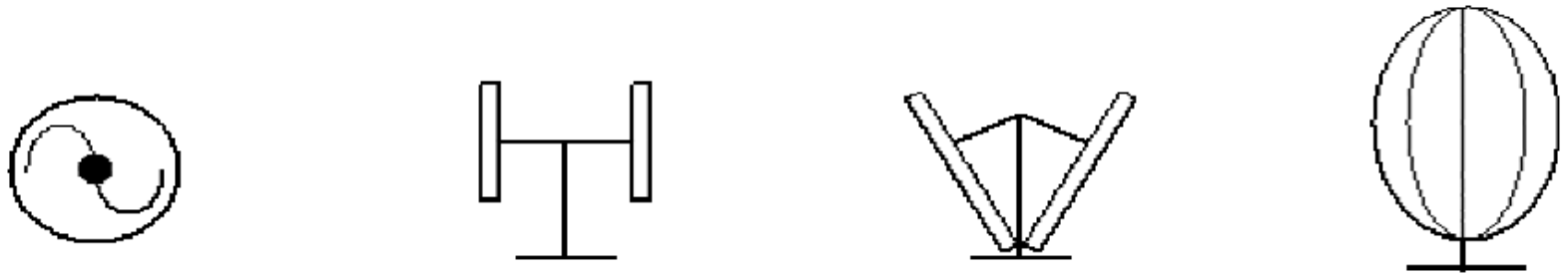




- Library\Control\Sources\SquareWave
- Library\PowerConverters\Inverters2phase\vsi2p
- Library\Control\FieldOrientedControl\HystereseCurrentControlSinglePhase

風力發電機模擬

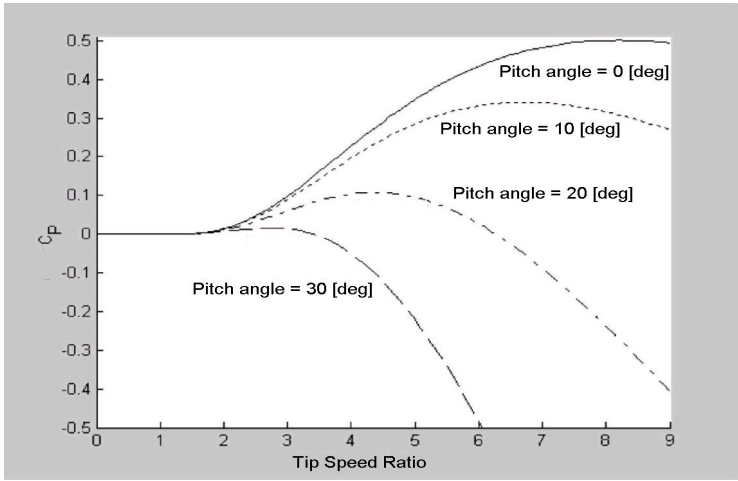

Horizontal axis
single-bladed
double-bladed
three-bladed
multi-bladed
up-wind
down-wind


Savonius
Darrieus

風力發電機模擬

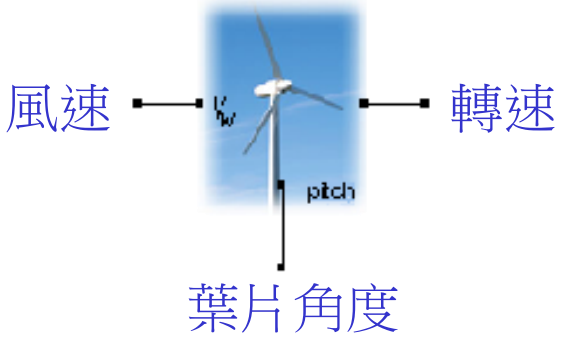
- 風機模型：
  - 隨pitch與風速變動
  - 輸出功率:

$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2} v_{wind}^3$$

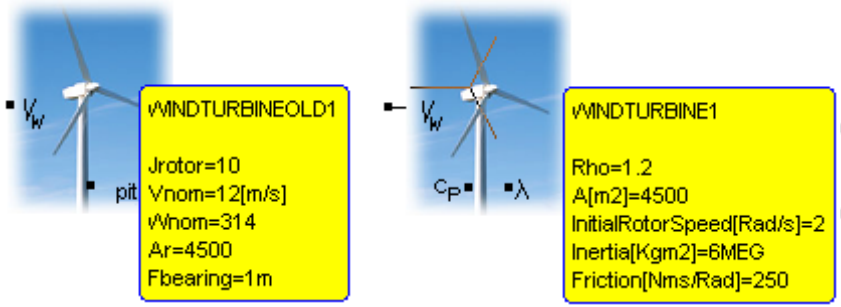


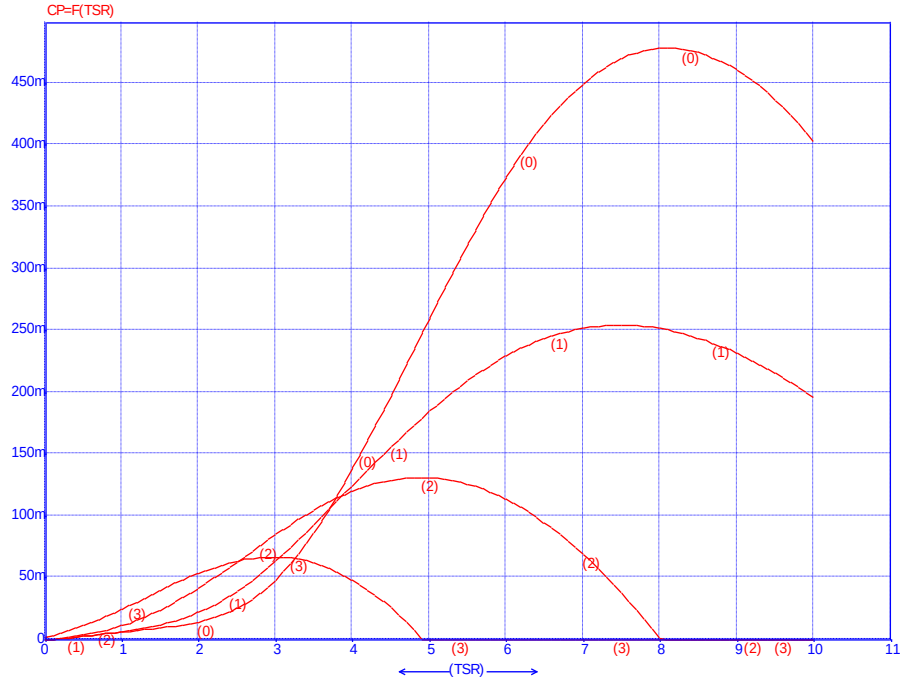
  - » Pm = Mechanical turbine output power (W)
  - » cp = Performance coefficient of the turbine
  - » rho = Air density (kg/m3)
  - » A = Turbine swept area (m2)
  - » vwind = Wind speed (m/s)
  - » Lambda = Tip speed ratio of the rotor blade tip speed to wind speed
  - » beta = Blade pitch angle (degrees)

- 系統模擬：
  - 風力發電機
  - Drive Shaft 傳動軸
  - 發電機與整流器



風力發電機模擬





$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2} v_{wind}^3$$

$$c_p(\lambda, \beta) = c_1\left(\frac{c_2}{\lambda_i} - c_3\beta - c_4\right)e^{\frac{-c_5}{\lambda_i}} + c_6\lambda$$

Lambda

- Tip speed ratio of the rotor blade tip speed to wind speed

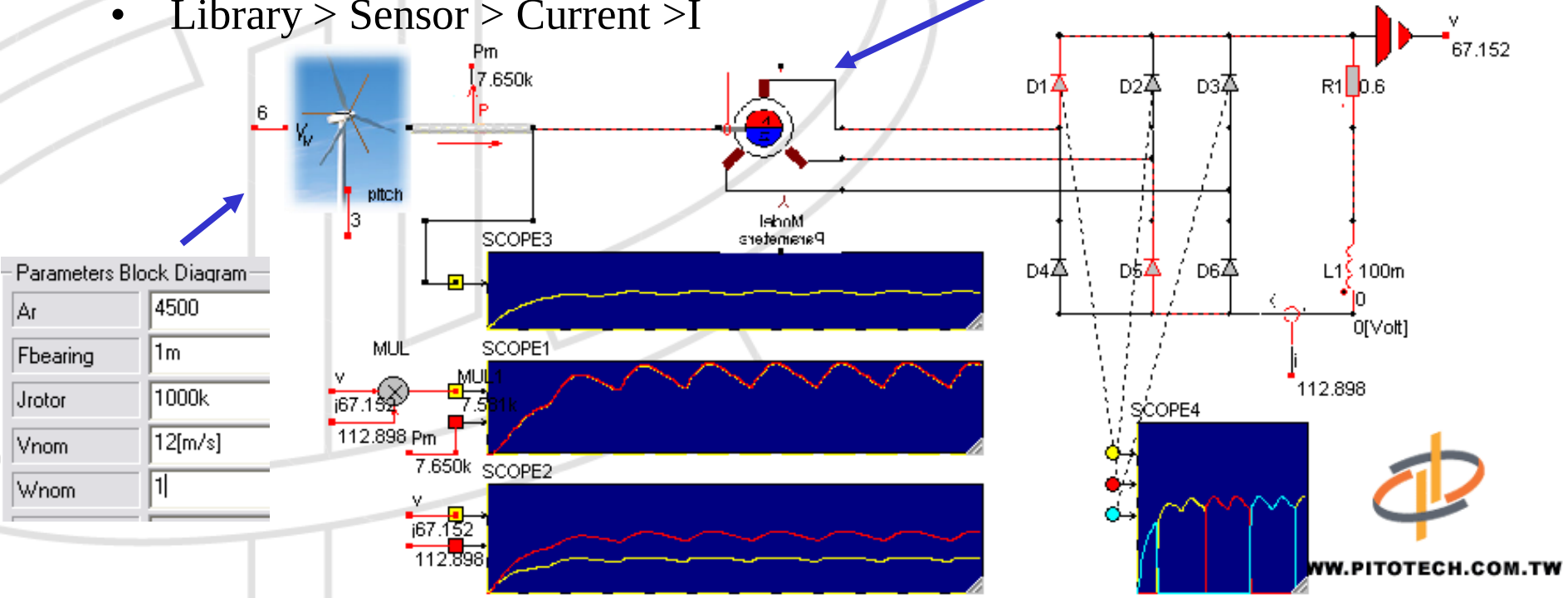
Beta

- Blade pitch angle (deg)

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}$$

風力發電機模擬

- 模型建立– 1：
- Library > GreenEnergy > Wind > Windturbine
- Library > Sensor > Rotational > Power
- Library > ElectricalMachines > PMSM > PMSM
- Library > Sensor > Voltage > v
- Library > Sensor > Current >I



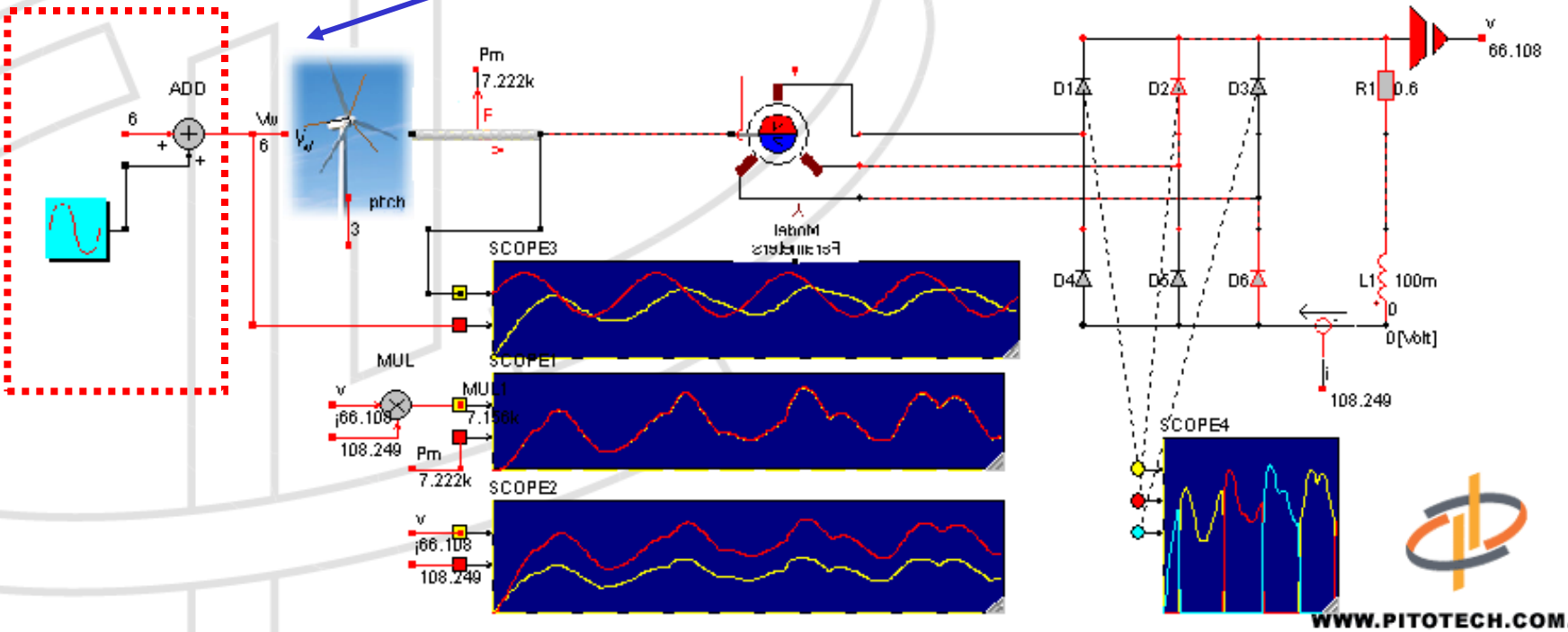
風力發電機模擬

- 模型建立– 2：變動風速
- Library > control > sources > sin
- Blocks > math > add

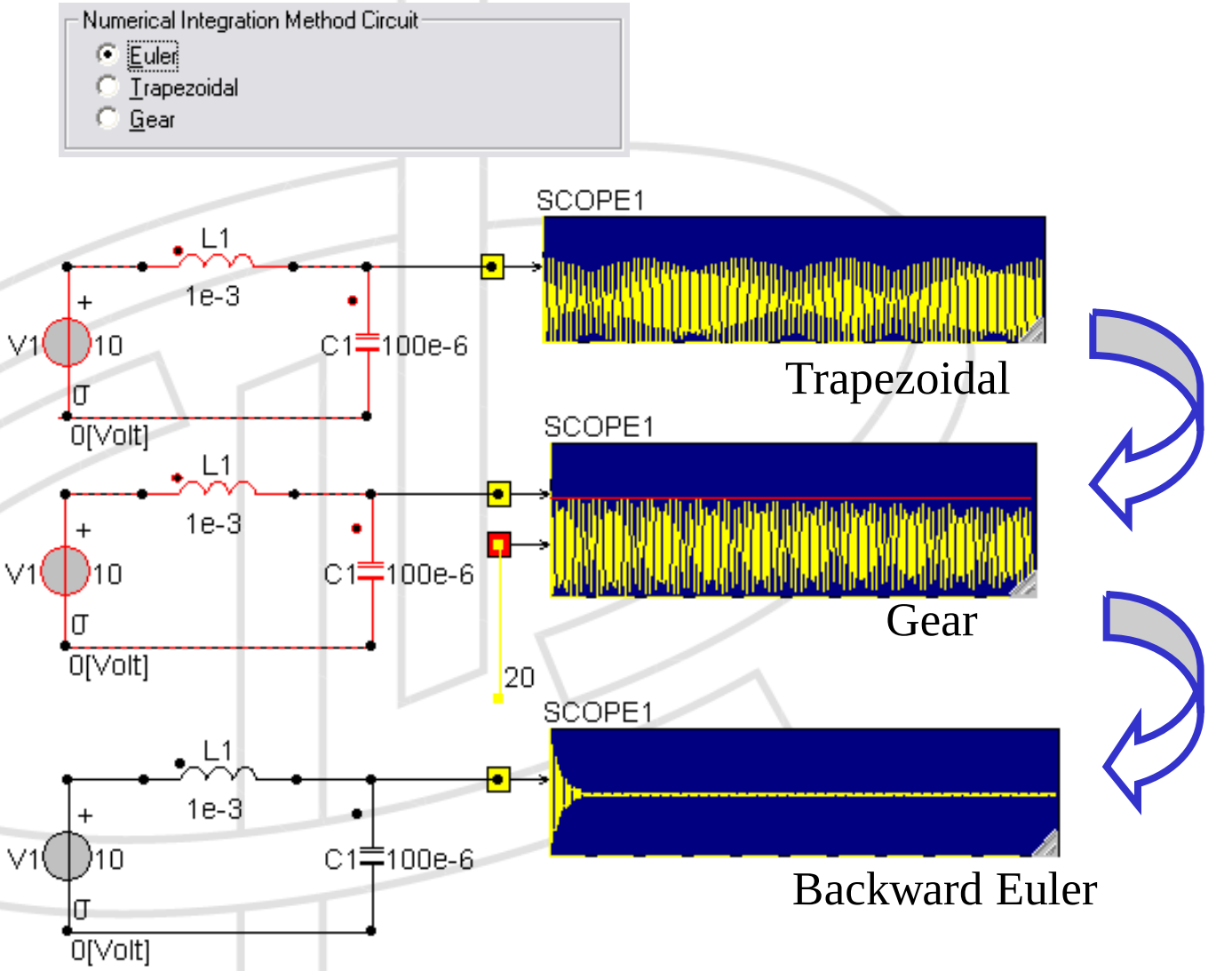
將風速變為週期性弦波，參數如右。

Parameters Block Diagram

Amplitude	2
Frequency(Hz)	0.2
Phase(0-360)	0



數值分析方法



考慮到實際 loss

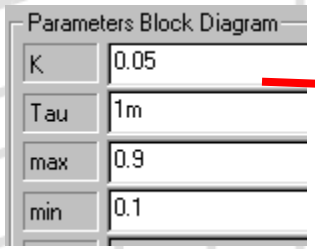
More damping

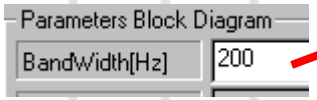
Session III: 綠能電力電子系統控制與管理 -使用CASPOC軟體-

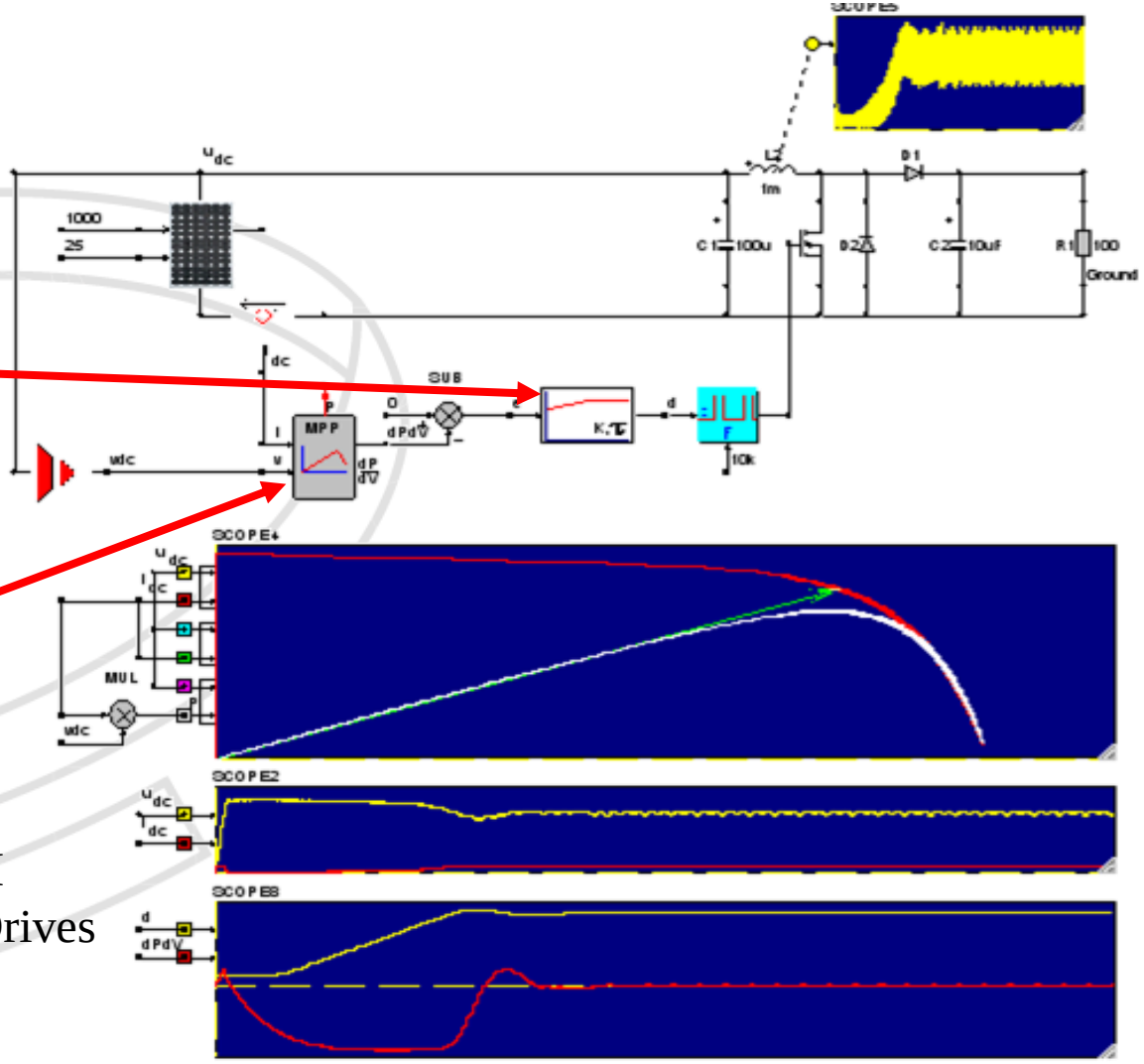
- 最大功率追蹤(Maximun power point tracking)
- 控制演算法設計(control algorithm), 數學運算子,電路感測器的使用與運算
- 多層次系統模擬(Multilevel simulation),電動機與發電機的使用- 電路、機械、數學元件混雜實驗設計
- 磁、熱分析相關－使用有限元素分析工具

太陽能電池模擬

- MPP(最大功率追蹤)



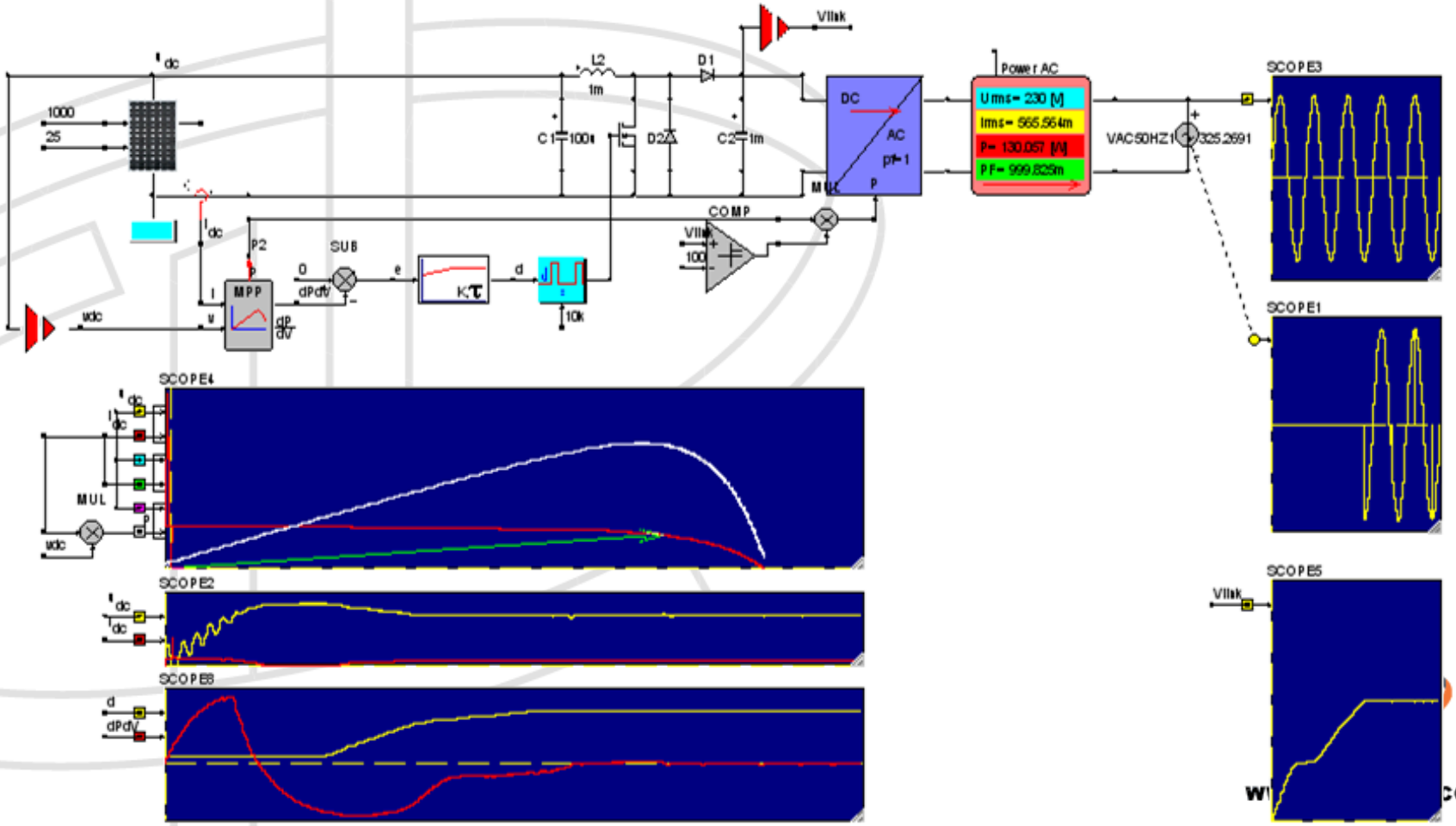




- Library\Control\SMPS\PWM
- Library\AdvancedElectricalDrives \Control\Scalar\PILimited

太陽能電池模擬

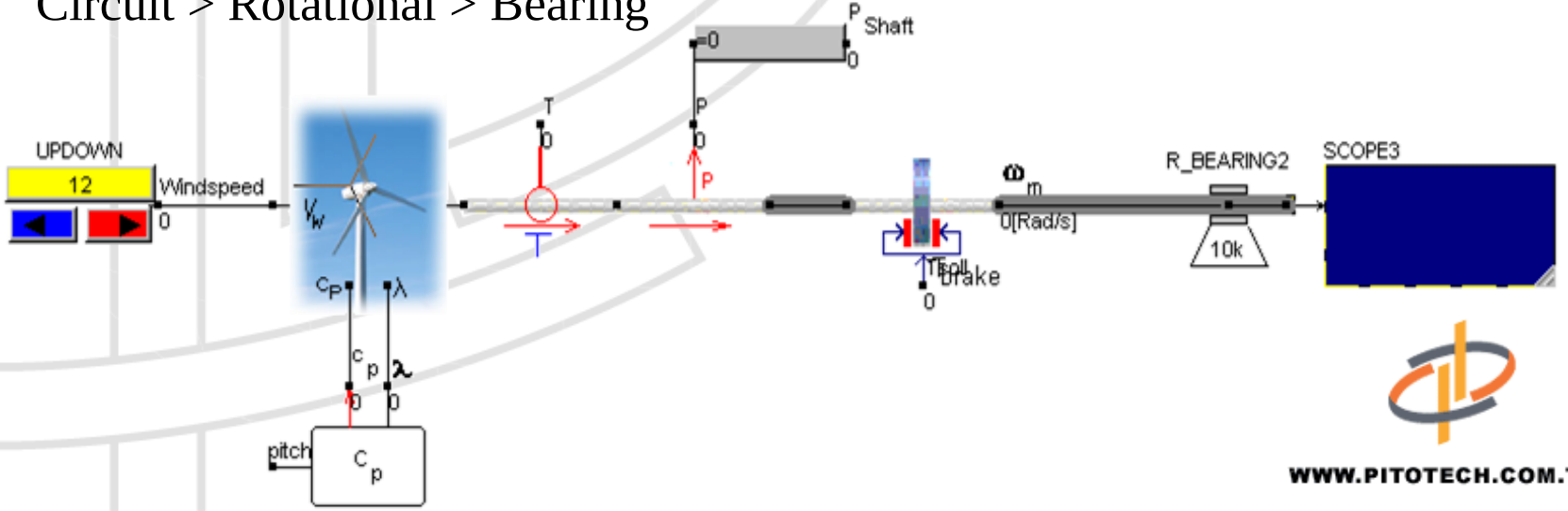
- 與市電併連並加入MPP(最大功率追蹤)



風力發電機模擬

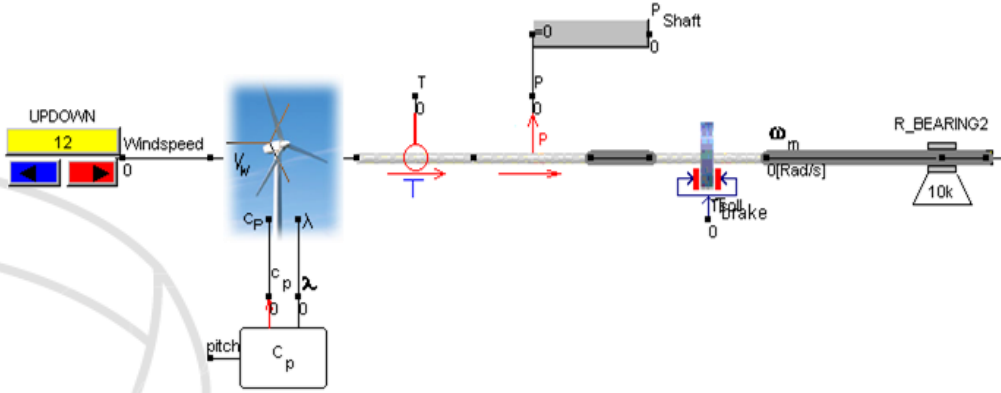
- 模型建立：最大功率追蹤
- Blocks > Source > Updown
- Library > GreenEnergy > Wind > Windturbine
- Library > GreenEnergy > Wind > CppHeier
- Library > Sensor > Rotational > Torque
- Library > Sensor > Rotational > Power
- Library > Sensor > Rotational > Brake
- Blocks > Sinks > ShowXY
- Circuit > Rotational > Bearing

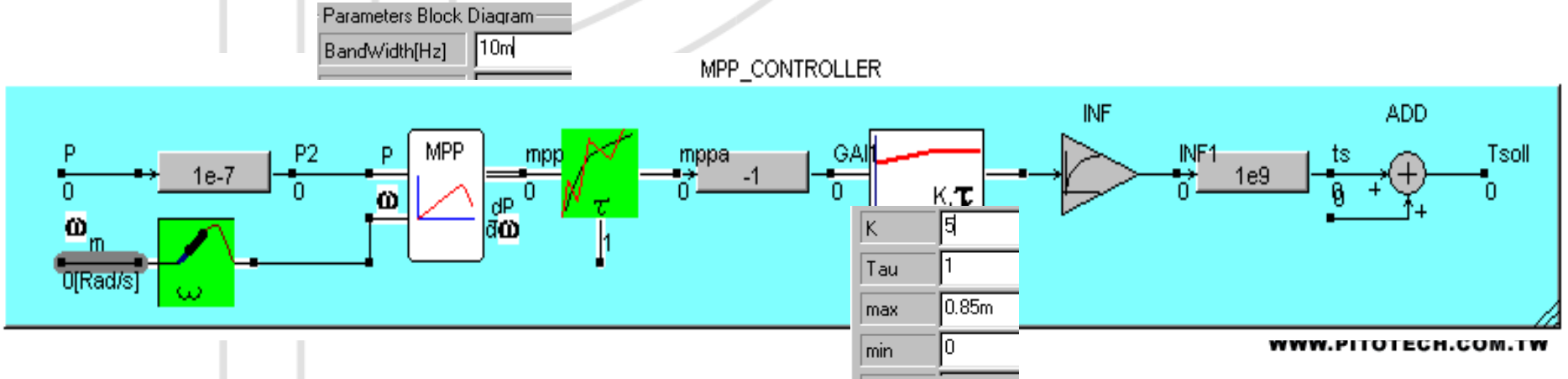
A[m2]	4500
Friction[Nms/Rad]	250
Inertia[Kgm2]	6MEG
InitialRotorSpeed[Rad/s]	2
Rho	1.2



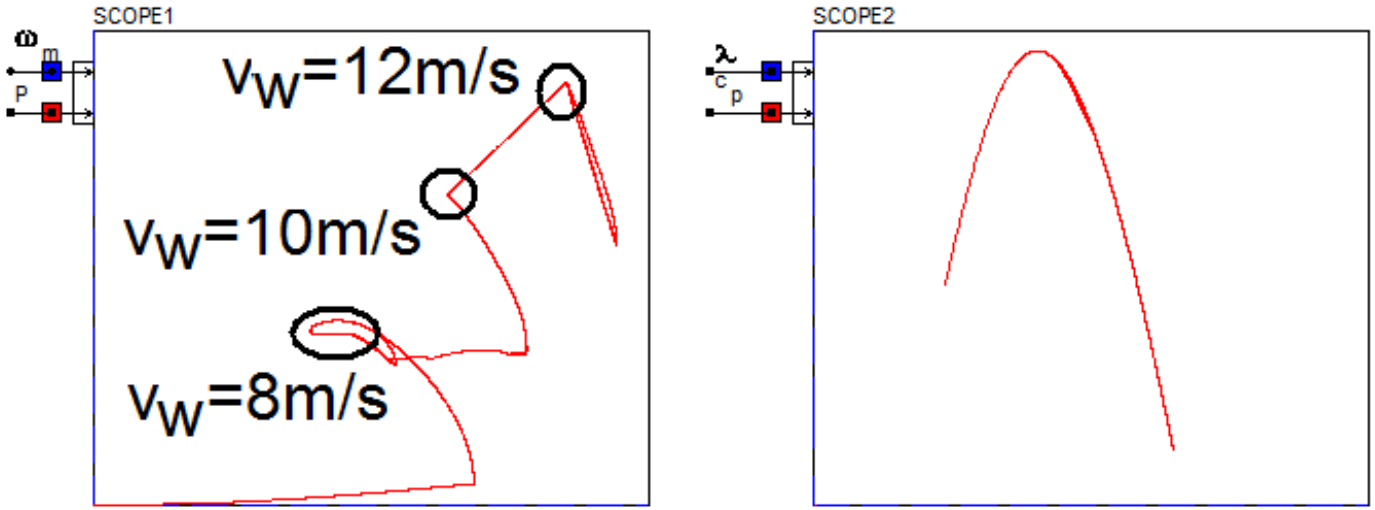
風力發電機模擬

- 模型建立：最大功率追蹤
- Blocks > Math > GAI
- Blocks > Integrator > INF
- Blocks > Math > ADD
- Library > Sensor > Rotational
- Library > GreenEnergy > Wind > MPPwindpower
- Library > Control > Controllers > MovingAverage
- Library > AdvancedElectricalDrives > Control > Scalar > PILimited



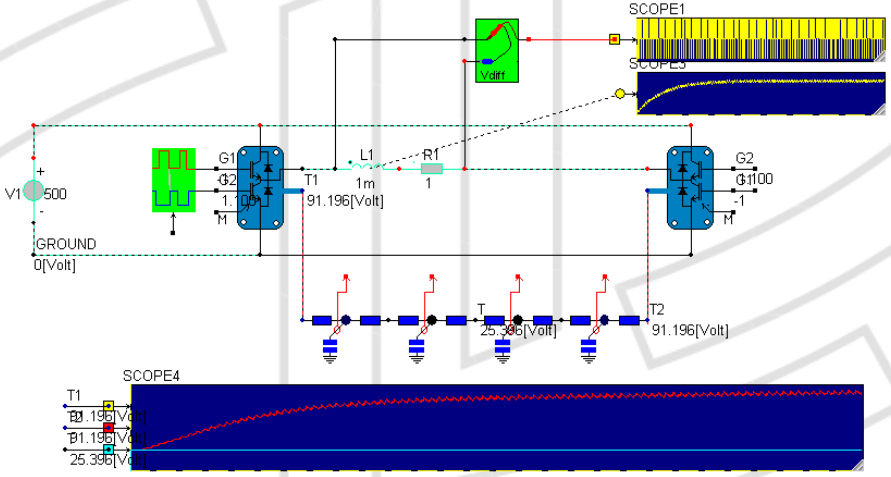


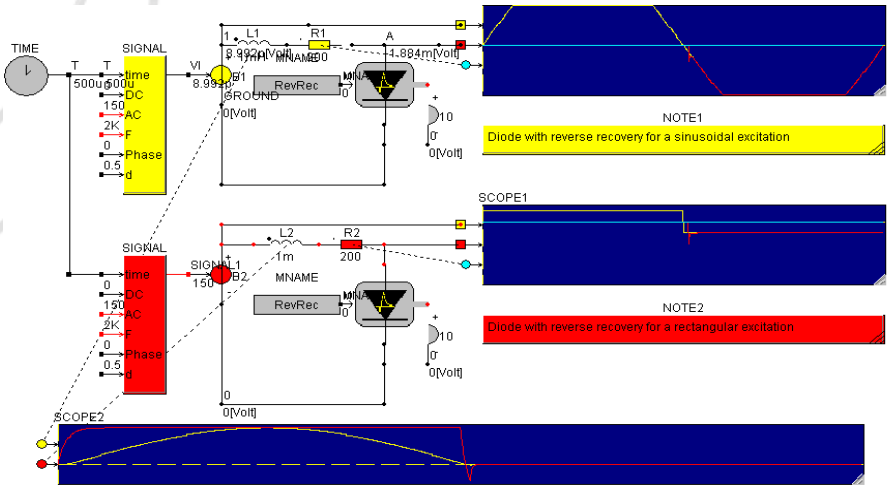
風力發電機模擬



Semiconductor Detailed and Fast

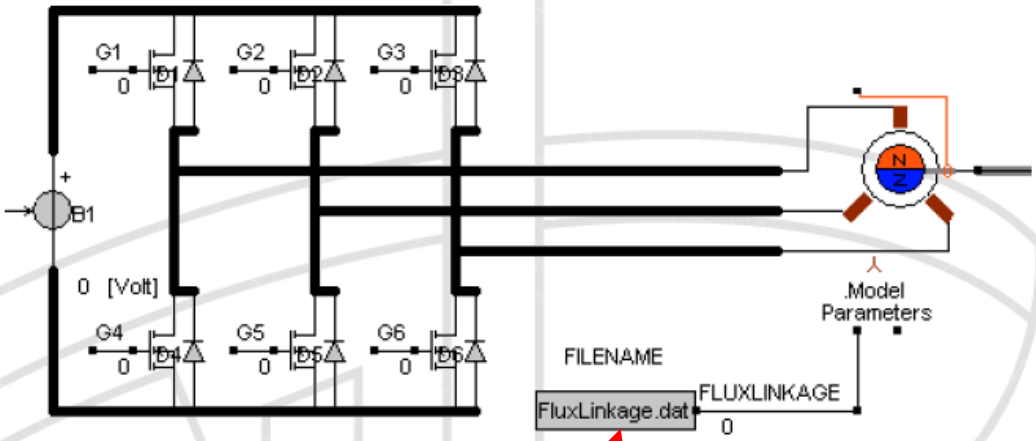
- MOSFET模型的非線性特點
- IGBT電流尾巴
- 二極體模型的recoverse recovery
- 快速損益預估
- Coupling to thermal models
- Include parasitic wire inductance and bus-bar capacitance in the circuit.

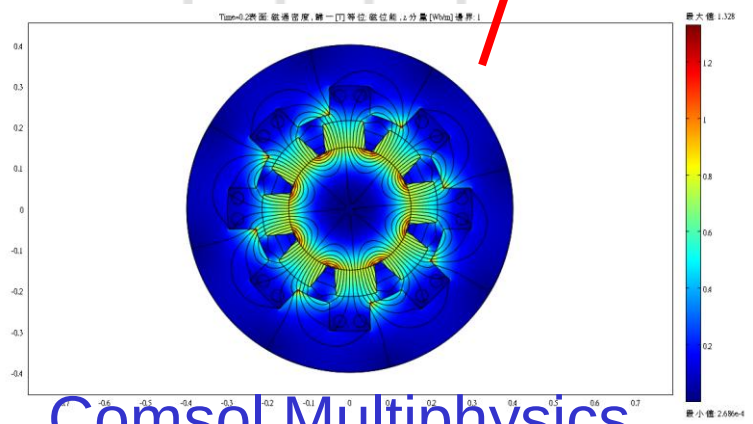




- \Samples\Semiconductors\diode\CompareReverseRecoverySinusoidalRectangle.csi
- \Samples\Semiconductors\IGBT\BridgeThermal.csi

Data-Exchange and FEM Co-Simulation





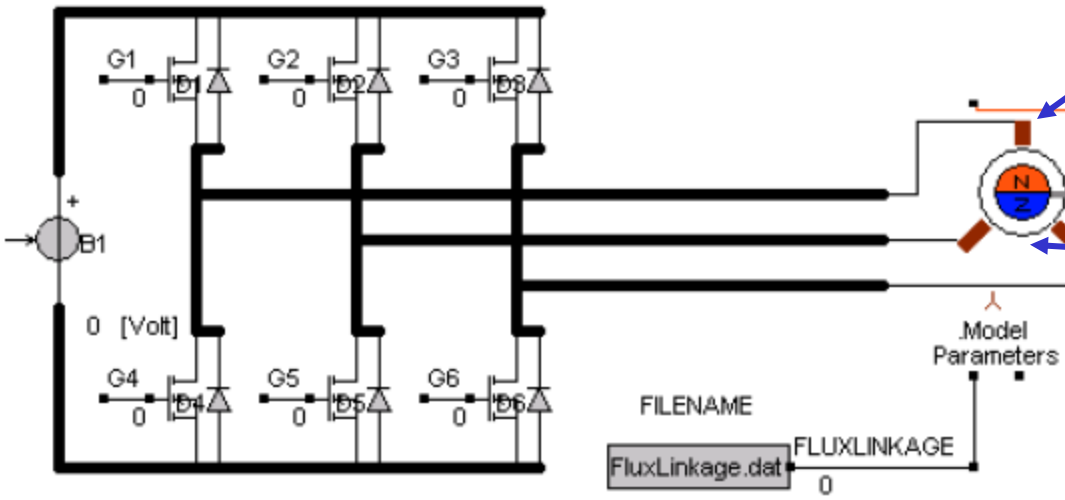
Comsol Multiphysics

- True Co-Simulation for complex electrical machines and linear actuators.
- Include eddy currents(渦電流) and losses in the co-simulation.
- Optimize your control with non-linear machine models parameters, look-up tables and transient co-simulation.
- Co-simulation with Simulink and data-exchange with Comsol Multiphysics gives you the power to any new type of electrical machine.

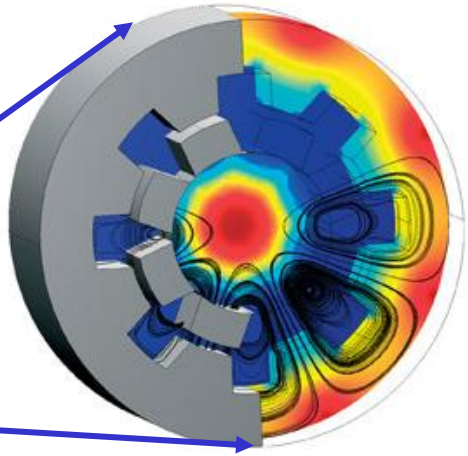
Co-Simulation - ex1

CASPOC 電力電子系統模擬
與 COMSOL Multiphysics 有限元素分析

CASPOC 快速且容易地從 FEM 軟體 COMSOL Multiphysics 提供的各類電子電機元件或致動器等模擬獲得系統模擬所需的資料



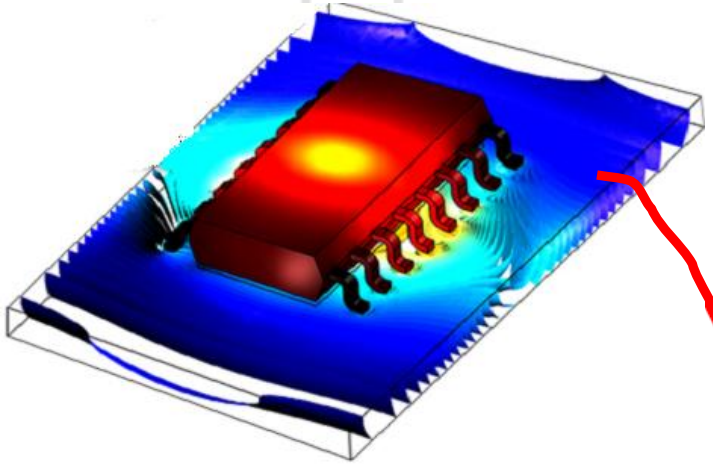
CASPOC Model



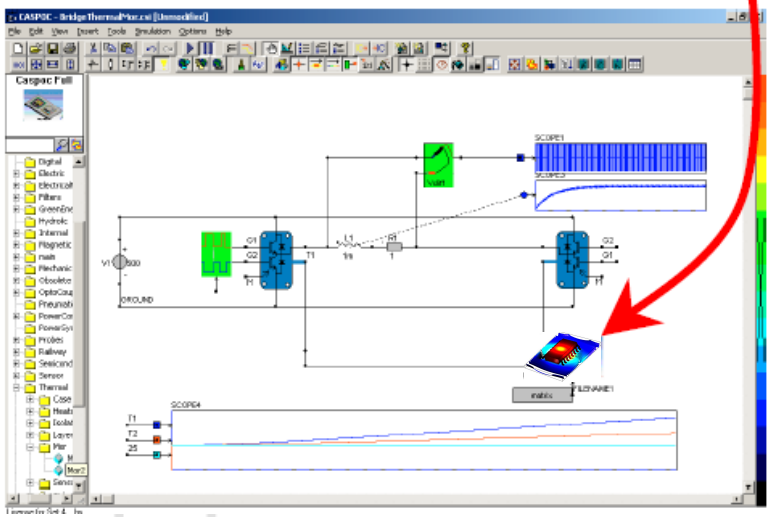
COMSOL Multiphysics Model

Co-Simulation - ex2

CASPOC 電力電子系統模擬
與 COMSOL Multiphysics 有限元素分析



COMSOL Multiphysics Model

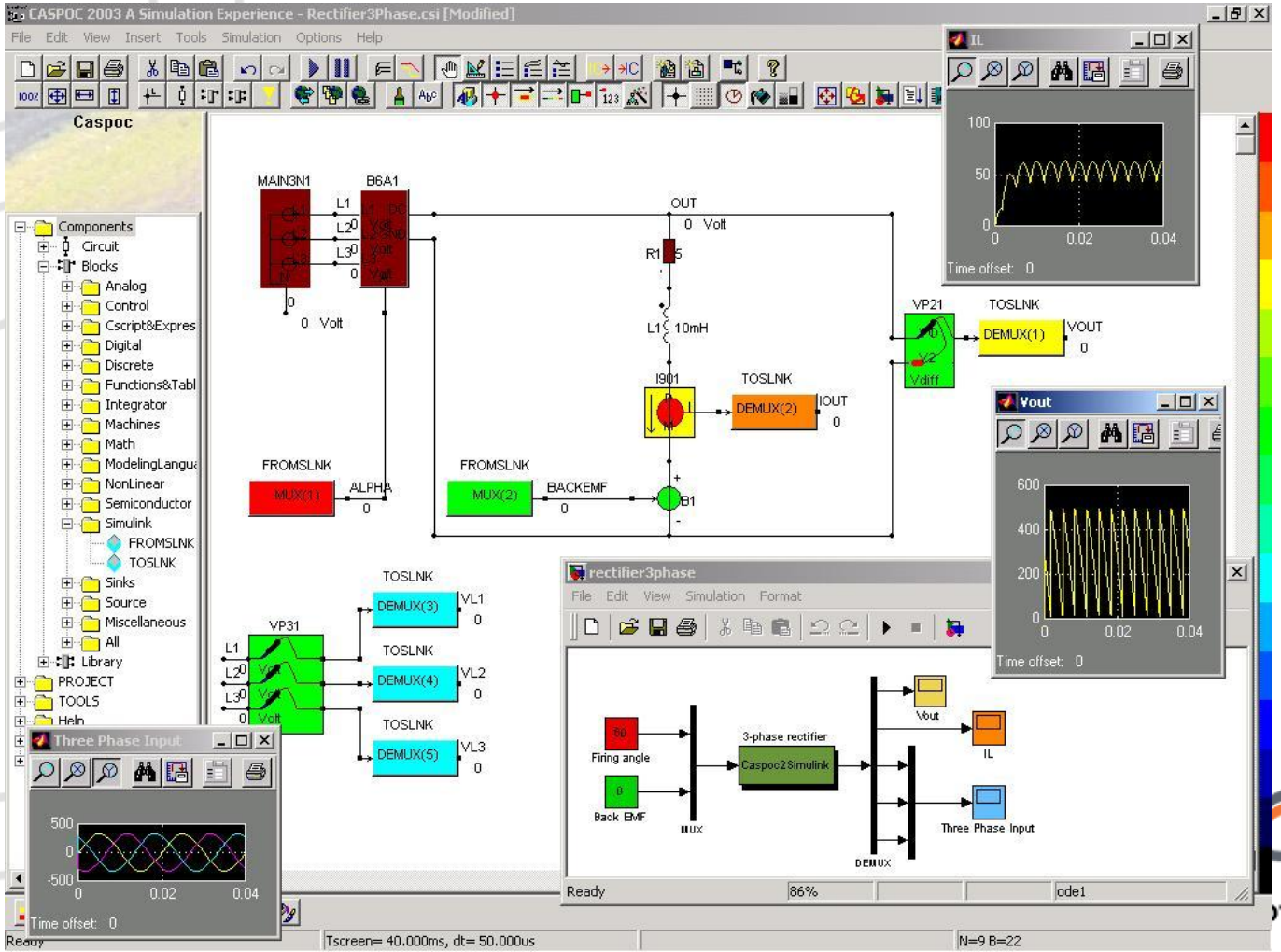


CASPOC Model

電力電子系統的散熱冷卻模型（如散熱片）可以利用 FEM 軟體 COMSOL Multiphysics 準確的建立並模擬出元件功率損失的熱場分佈，提供電力電子元件系統模擬所需的散熱元件的資料

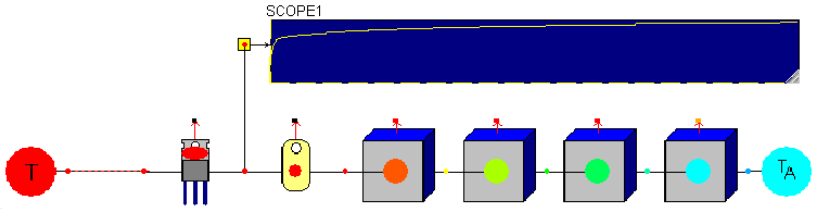
Co-Simulation – ex3

CASPOC 電力電子系統模擬
與 Matlab/simulink進行偶合模擬

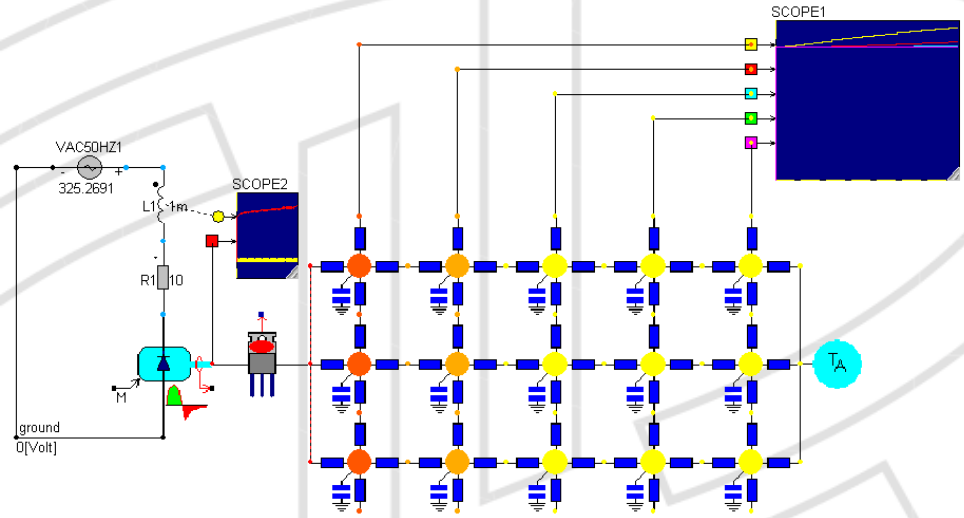


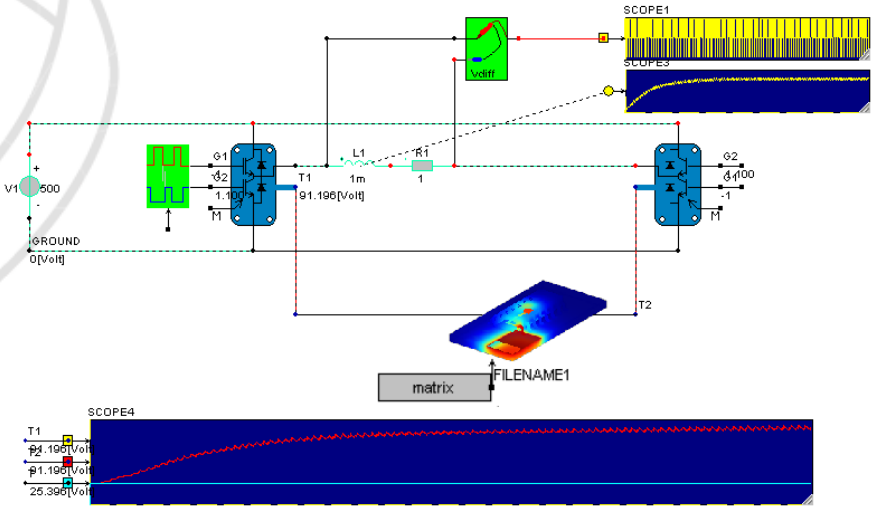
Heat Sink modeling

- 散熱器可與半導體耦合
- 預設熱材料性質參數, 並可讀取data表.
- 現有可用的Heat Sink元件
- 可讀取Comsol輸出之材料特性表



T220 with heat sink and isolation layers

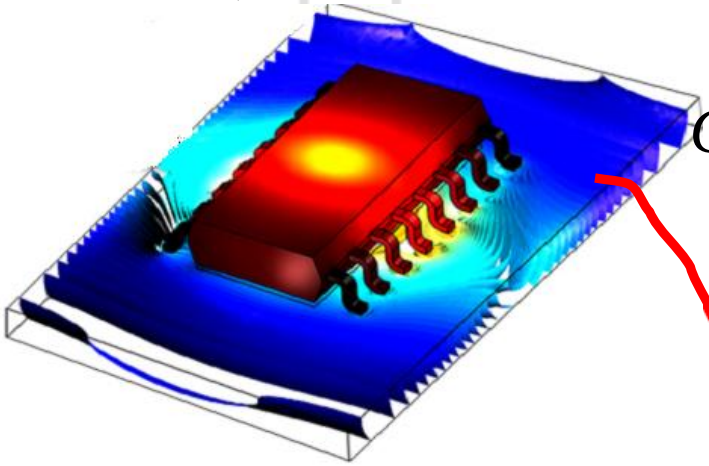




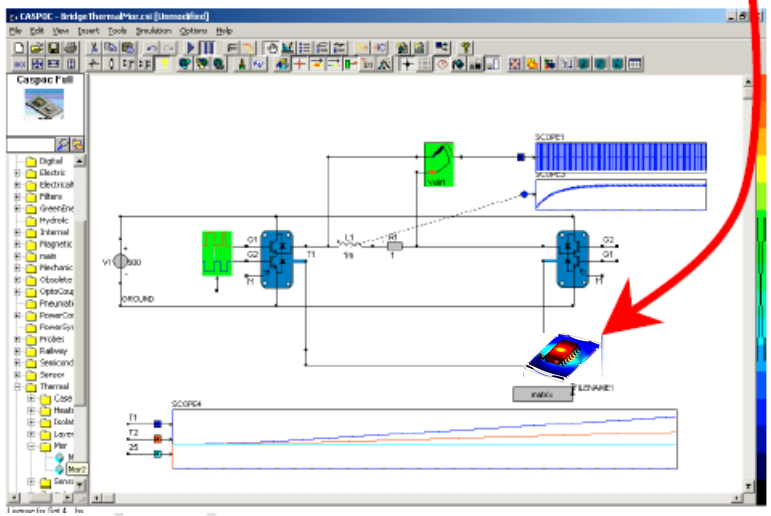
- C:\CASPOC2007\Samples\HeatSink\TO220_4LayerHeatSink.csi
- C:\CASPOC2007\Samples\HeatSink\RectifierHeatsink.csi
- C:\CASPOC2007\Samples\Semiconductors\IGBT\BridgeThermal.csi

Co-Simulation - ex2

CASPOC 電力電子系統模擬
與 COMSOL Multiphysics 有限元素分析



COMSOL Multiphysics Model

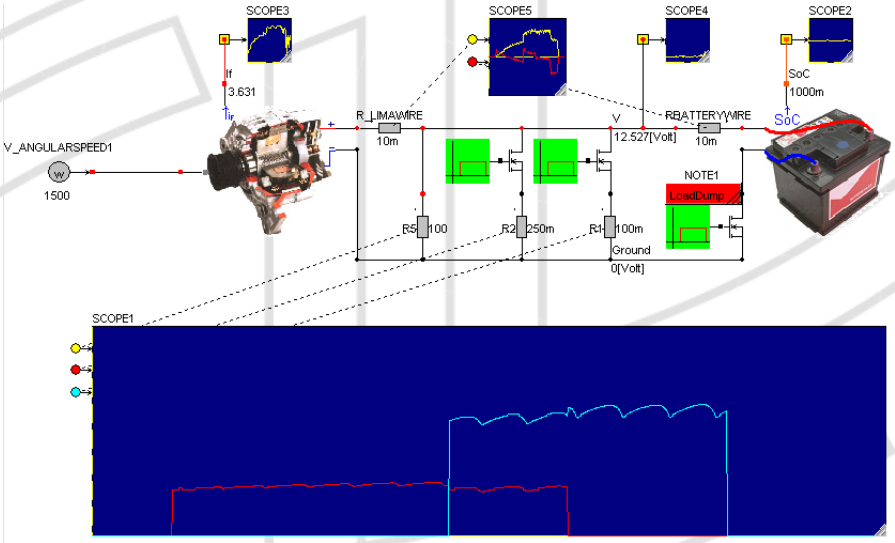


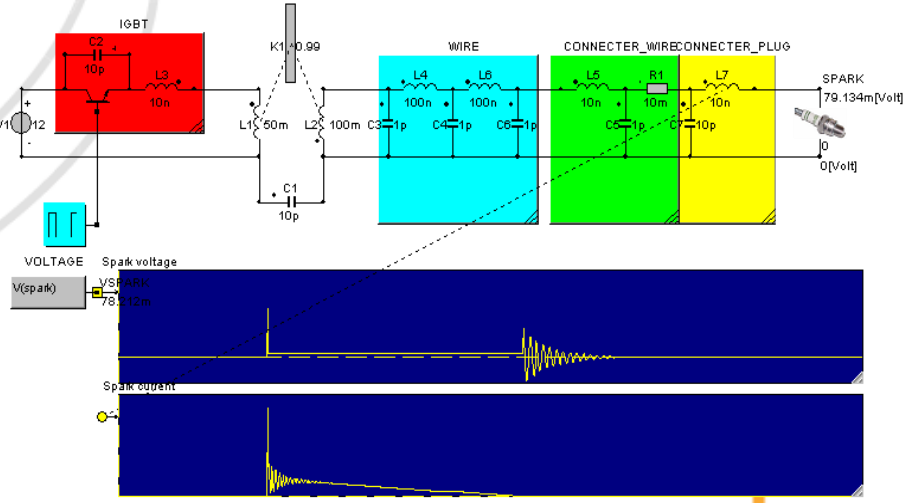
CASPOC Model

電力電子系統的散熱冷卻模型（如散熱片）可以利用 FEM 軟體 COMSOL Multiphysics 準確的建立並模擬出元件功率損失的熱場分佈，提供電力電子元件系統模擬所需的散熱元件的資料

Automotive Power Management

- 詳盡的交流發電機模型, 包含6 pulse整流器與控制器.
- 包含SOC電池模型, 與充放電阻抗
- 高電壓火星塞模型
- 雙向直流供應電, 包含電流限制與效益模型
- 電源管理中的駕駛循環模型(Drive cycle)

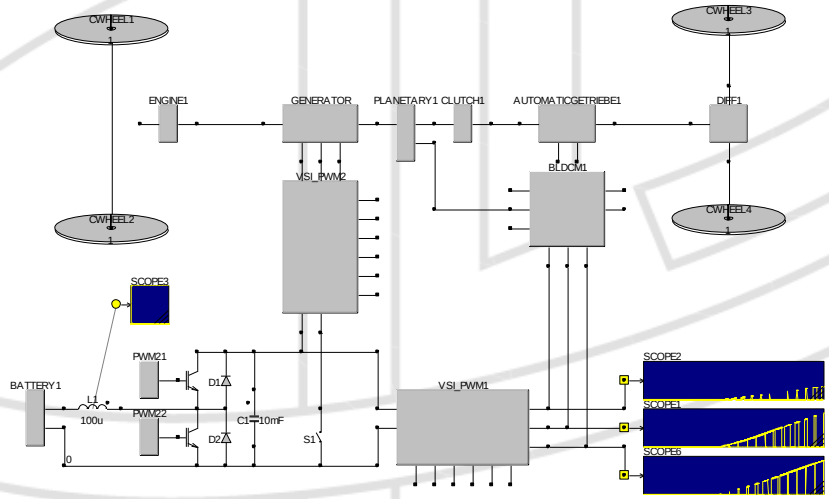


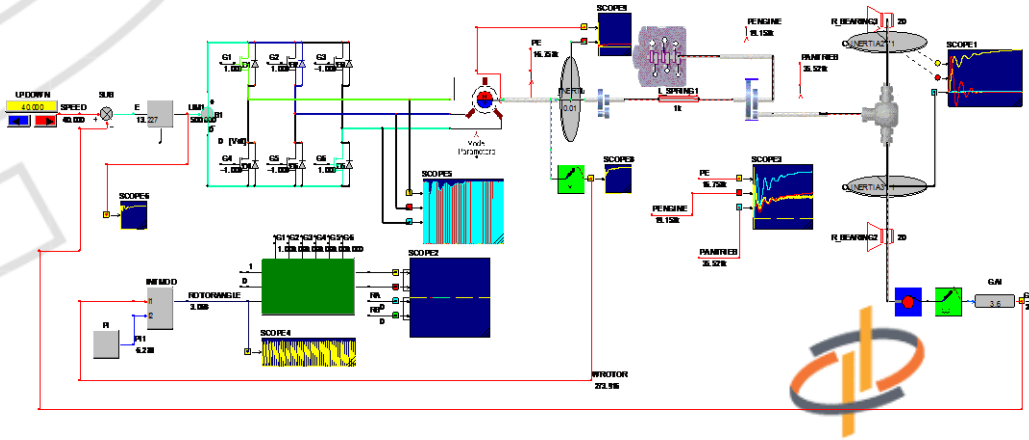


- C:\CASPOC2007\Samples\Automotive\PowerGrid\BordNetz.csi
- C:\CASPOC2007\Samples\Automotive\SparkPlug\Spark_FlyBack.csi

Hybrid Electric Vehicles

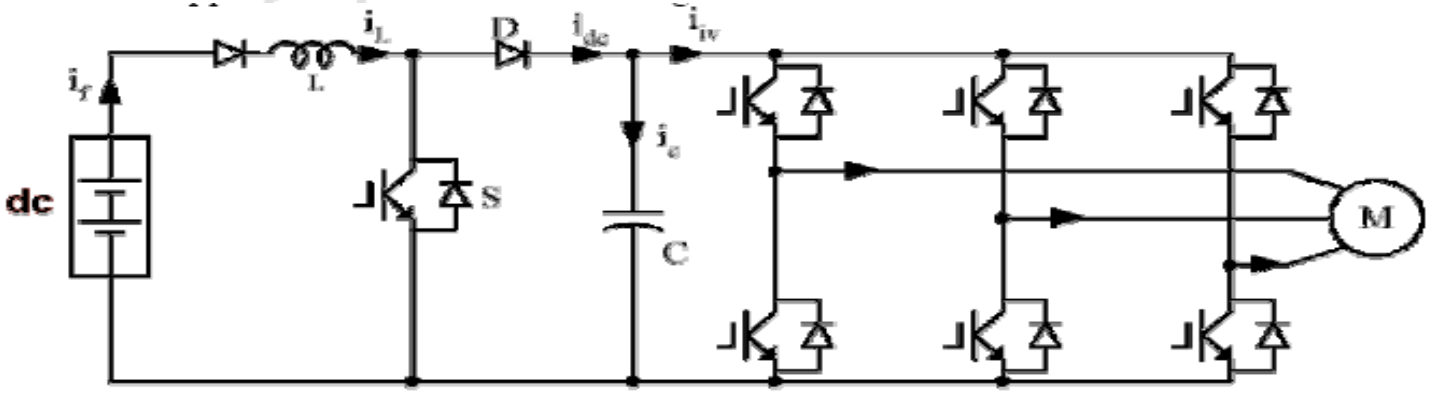
- 傳動系統
- Inverters with PWM and Field-Oriented Control
- 詳盡的非線性機械模型
- 詳盡的交流發電機模型, 包含6 pulse整流器與控制器.
- 包含SOC電池模型, 與充放電阻抗
- 高電壓火星塞模型
- 雙向直流供應電, 包含電流限制與效益模型
- 電源管理中的駕駛循環模型(Drive cycle)

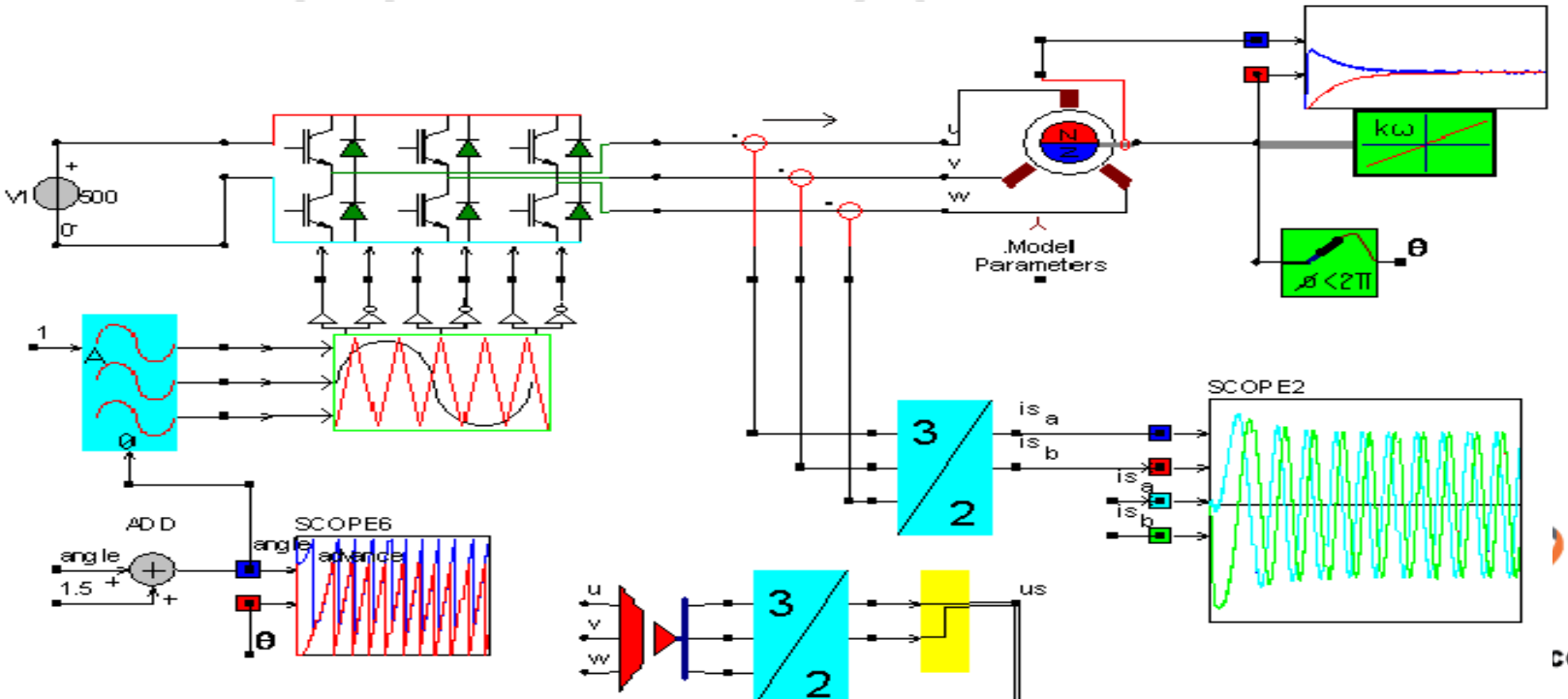




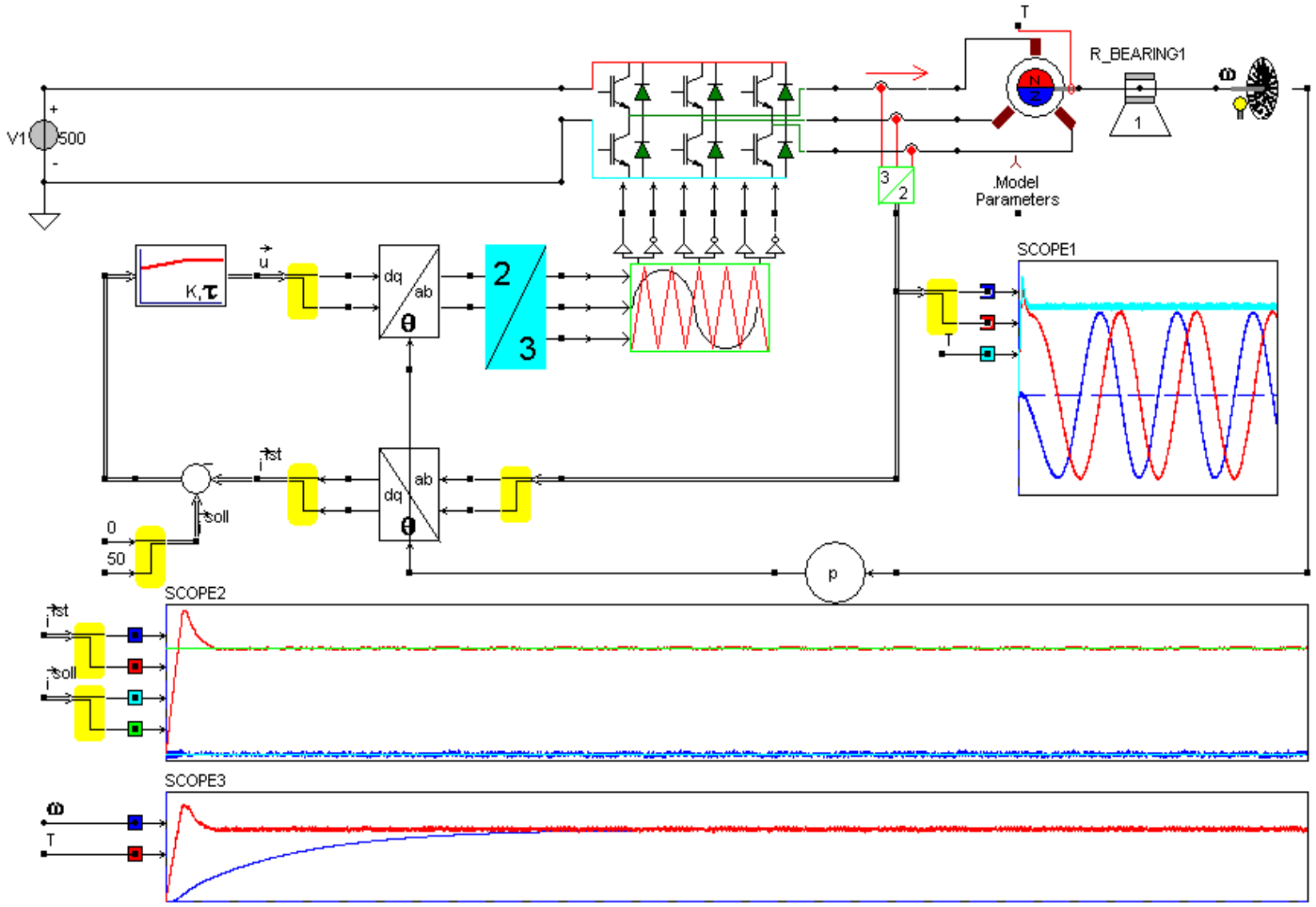
•Caspoc2007\Samples\Automotive\DriveTrain\hybrid4.csi

Inverter with PMSM





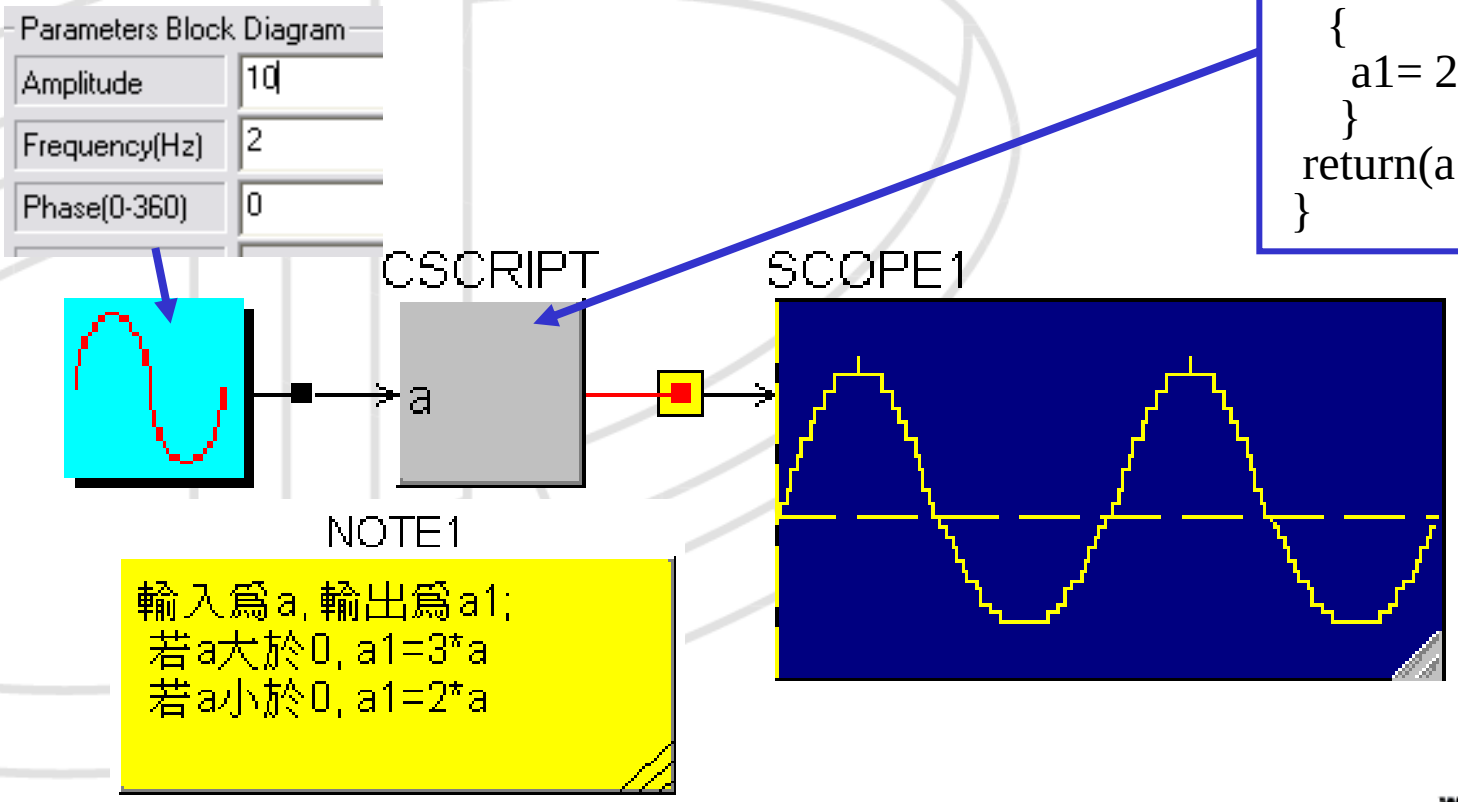
FOC of PMSM


T
R_BEARING1
ω
V1
500
1
3
2
.Model
Parameters
SCOPE1
K,τ
u
dq
ab
θ
2
3
T
i st
i soll
0
50
p
SCOPE2
SCOPE3
ω
T

加入C Script

- 模型建立–1
- Library > Control > Sources > sin
- Blocks > Cscript&Expression > CSCRIPT

```
int a1;
main()
{
  if (a>0)
    {
     a1=3*a;
    }
   else
   {
    a1= 2*a;
    }
 return(a1);
}
```

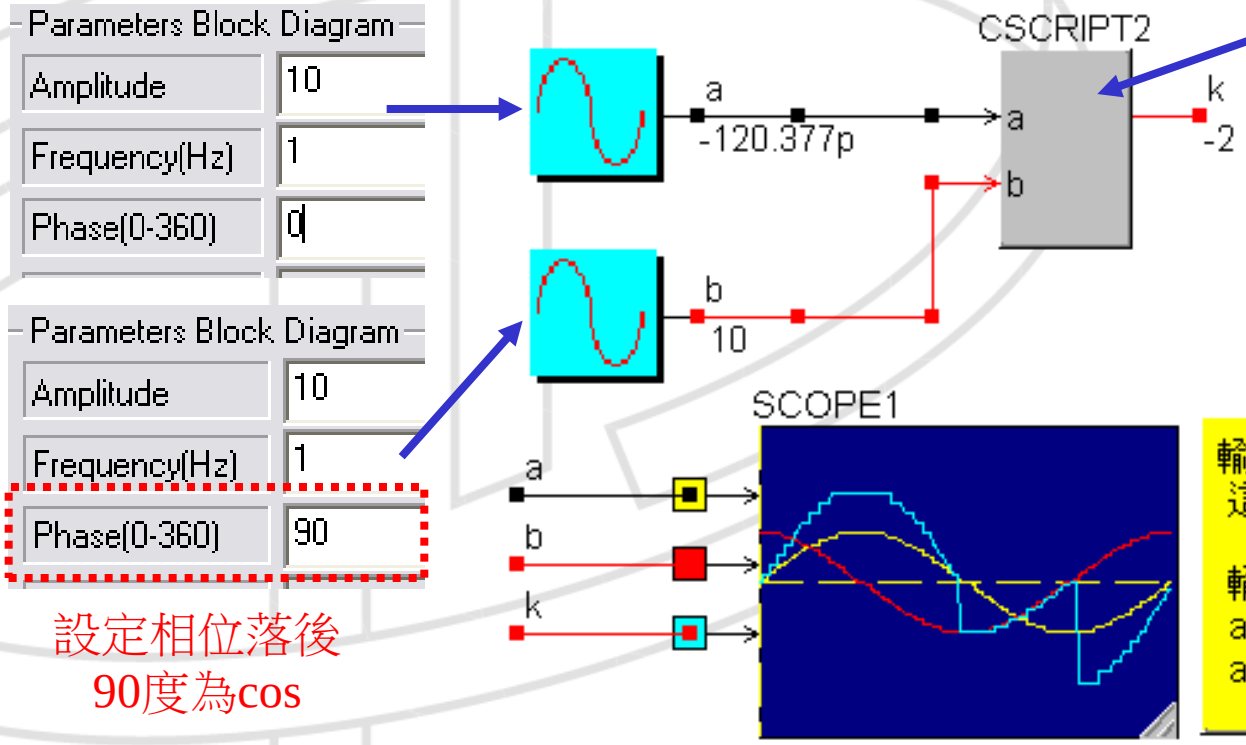


加入C Script

- 模型建立–2
- Library > Control > Sources > sin
- Blocks > Cscript&Expression > CSCRIPT2

```
int k;

main( )
 {
    if (a>0) || (b>0)
    {
      k=2*a;
    }
   else
    {
      k=b;
    }
 return k;
}
```



設定相位落後
90度為cos

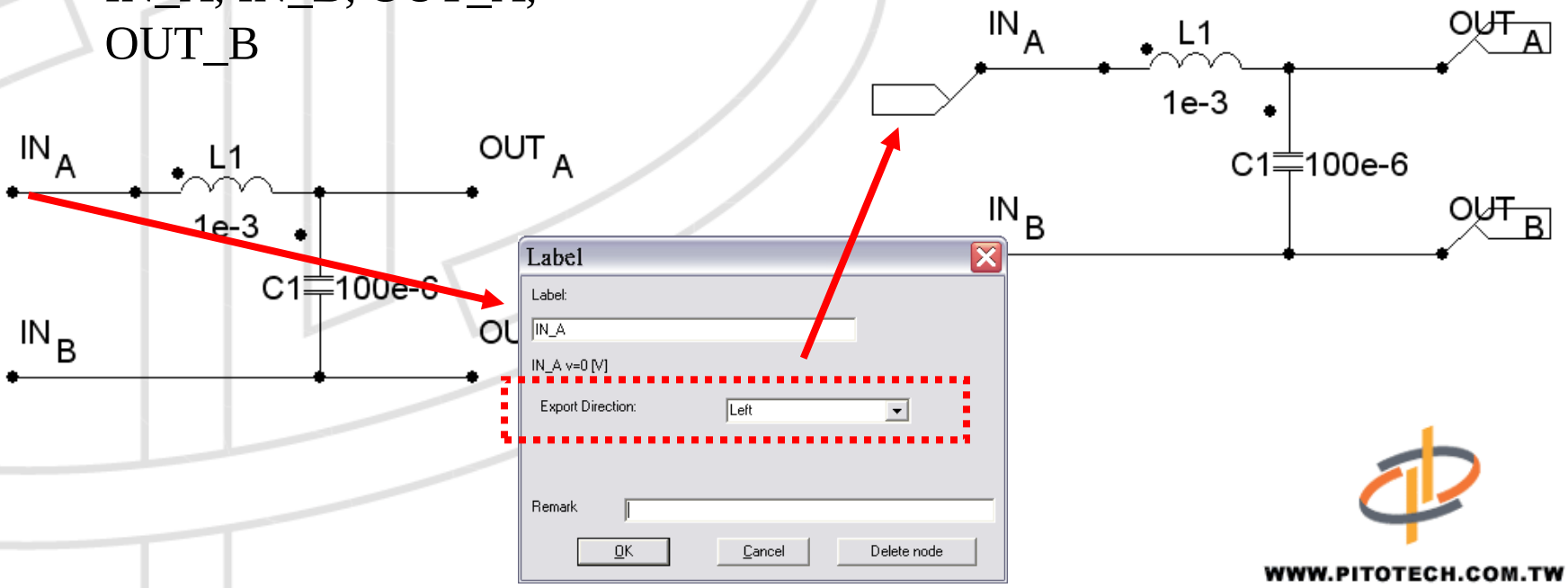
NOTE1

輸入爲a, b,
這裡的a,b分別爲sin跟cos.

輸出爲k
a,b只要其中一個大於0, k就等於2*a
a,b皆小於0時,k就等於b

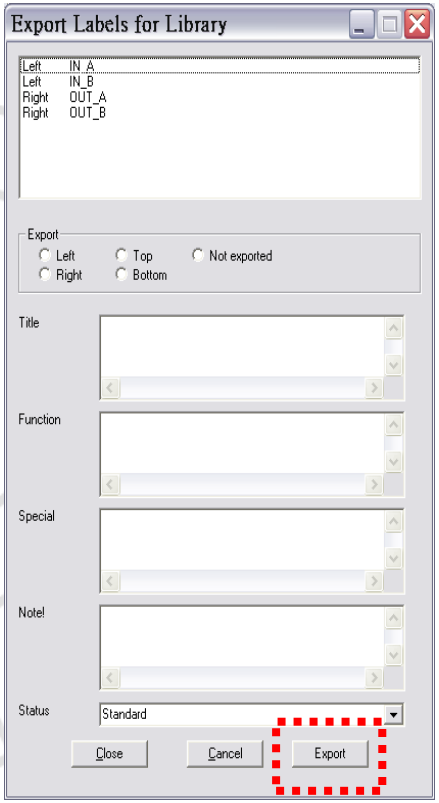
模型客製化

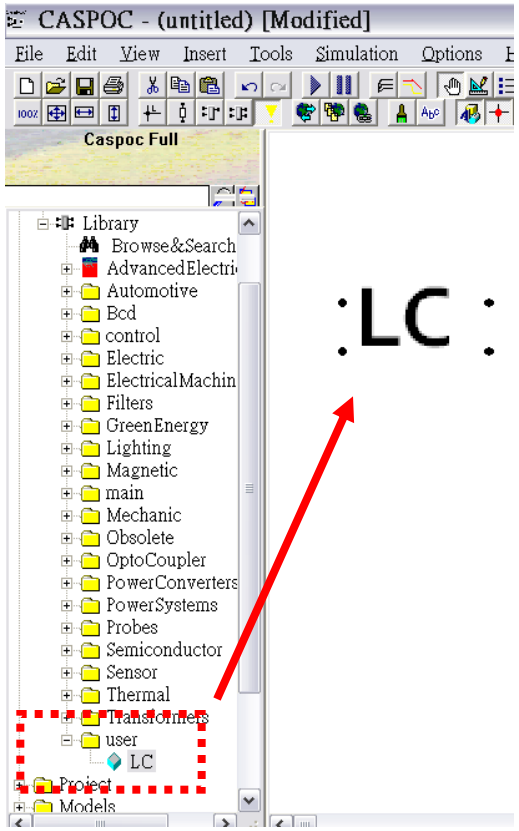
- 模型建立–1
  - 隨意放置兩個元件
  - Circuit > RLC > L and C
  - 將元件連接如右所示，並將節點label分別設定為IN_A, IN_B, OUT_A, OUT_B
  - 在label上按下右鍵，將四個label分別設定Export Direction為Left, Left, Right, Right



模型客製化

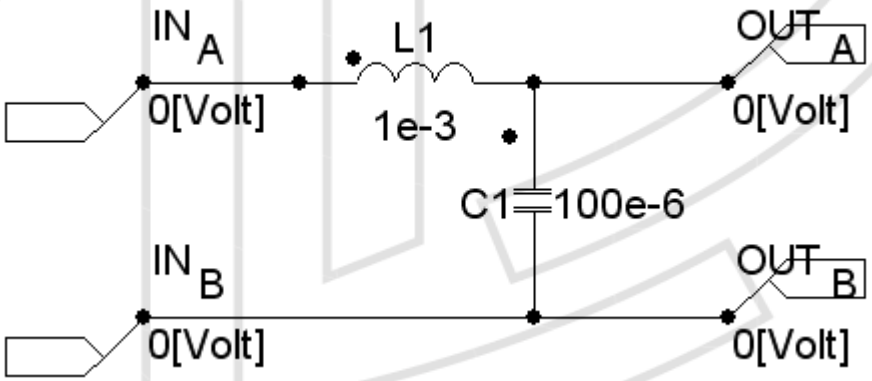
- 模型建立–2
  - 選擇Edit > Export Library
  - 點選右下角的Export
  - 將檔案儲存在:C:\CASPOC2007\Library\xxx (資料夾名稱可自己建立, 如user)
  - 檔名命為LC.lib (舉例)
  - 選擇View > Refresh TreeView
  - 選擇Library > user > 可看到新加入的LC檔名





模型客製化

- 模型建立–3
  - 可在C:\CASPOC2007\Library\user 新增一個*.bmp檔
  - 檔名須和.lib的一致, 如LC.bmp



Session IV：風電廠開發與規劃模擬 -使用WindPro軟體-

- 風能分布設計(ATLAS)與能源計算
- 風電廠(Windfarm): 風力發電機(WTG)建置、噪音處理、地理環境資料
- 陰影(Shadow)、視覺影響區域(ZVI)的影響分析

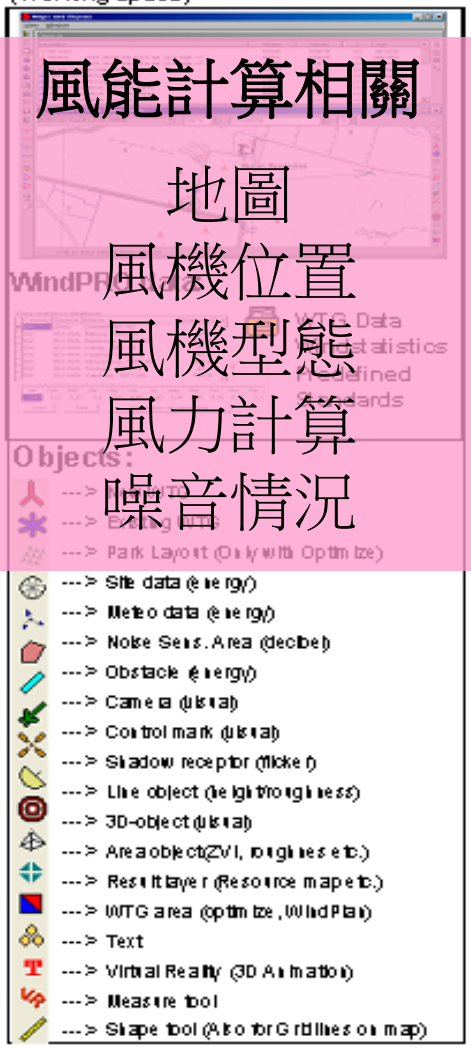
軟體模組


Energy
Optimize
Automatic optimisation of layout for maximum energy output
Park
Wind farm energy calculation including array losses based on one of the modules below.
NEW: Now also turbulence and RIX calculations
Resource
Calculation and presentation of Wind Resource Maps
CFD Interface
Data interface (import/export) to Windsim, Meteodyn and other CFD models
MCP/Statgen
MCP (Measure-Correlate-Predict) and generation of wind statistics
Meteo
Import logger data, analyze, validate and calculate
WAsP interface
Pre and post-processing of data calculated with WAsP
Atlas
Wind atlas calculation in non-complex terrain
Environment
Impact
Environmental impact for each neighbour with separate report
ZVI
Calculates Zones of Visual Influence for a specified area
Shadow
Calculation of Shadow impact (flickering)
Decibel
Noise calculations – Several country specific models included
Visualization
3D Animator
Virtual reality presentation of WTGs in an artificial rendered landscape
Animation
Animated presentation of a photomontage
Photomontage
Rendering of WTGs into landscape photo or artificial landscape
Grid & Planning
eGRID
Calculation of electrical grid connections
WindPLAN
Planning and/or site finding based on GIS data
Economy
WindBANK
Economic analysis of WTG projects
Basis
Basic module for all other modules – Can also be used separately. Contents: WTG Catalogue, Project Explorer with World Globe, Project Administration, Map handling, Map Composer, Terrain Profile viewer, etc.
For Windows 2000/XP/Vista

System Overview

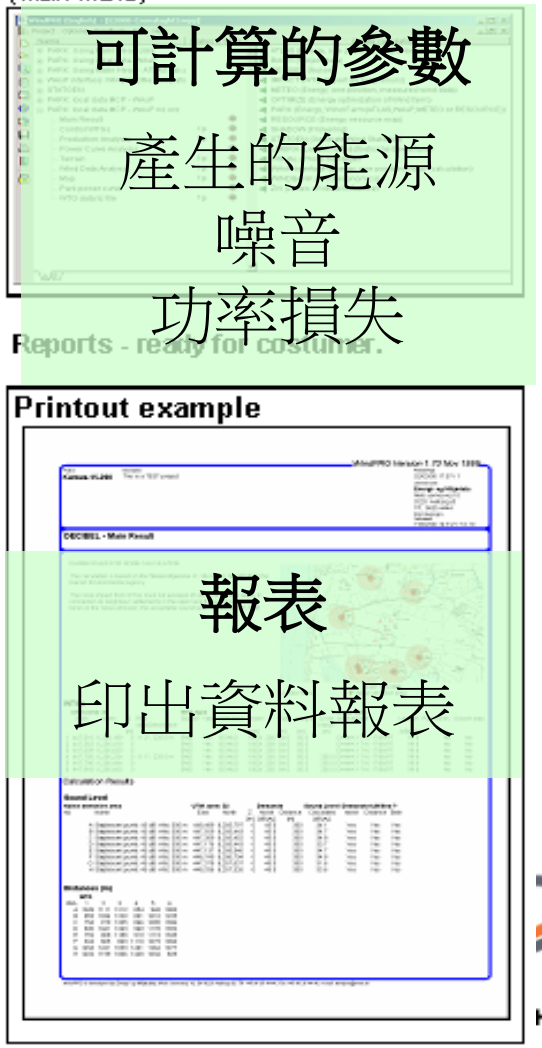
專案相關設定

名稱
座標
整合地圖資料



風能計算相關

地圖
風機位置
風機型態
風力計算
噪音情況



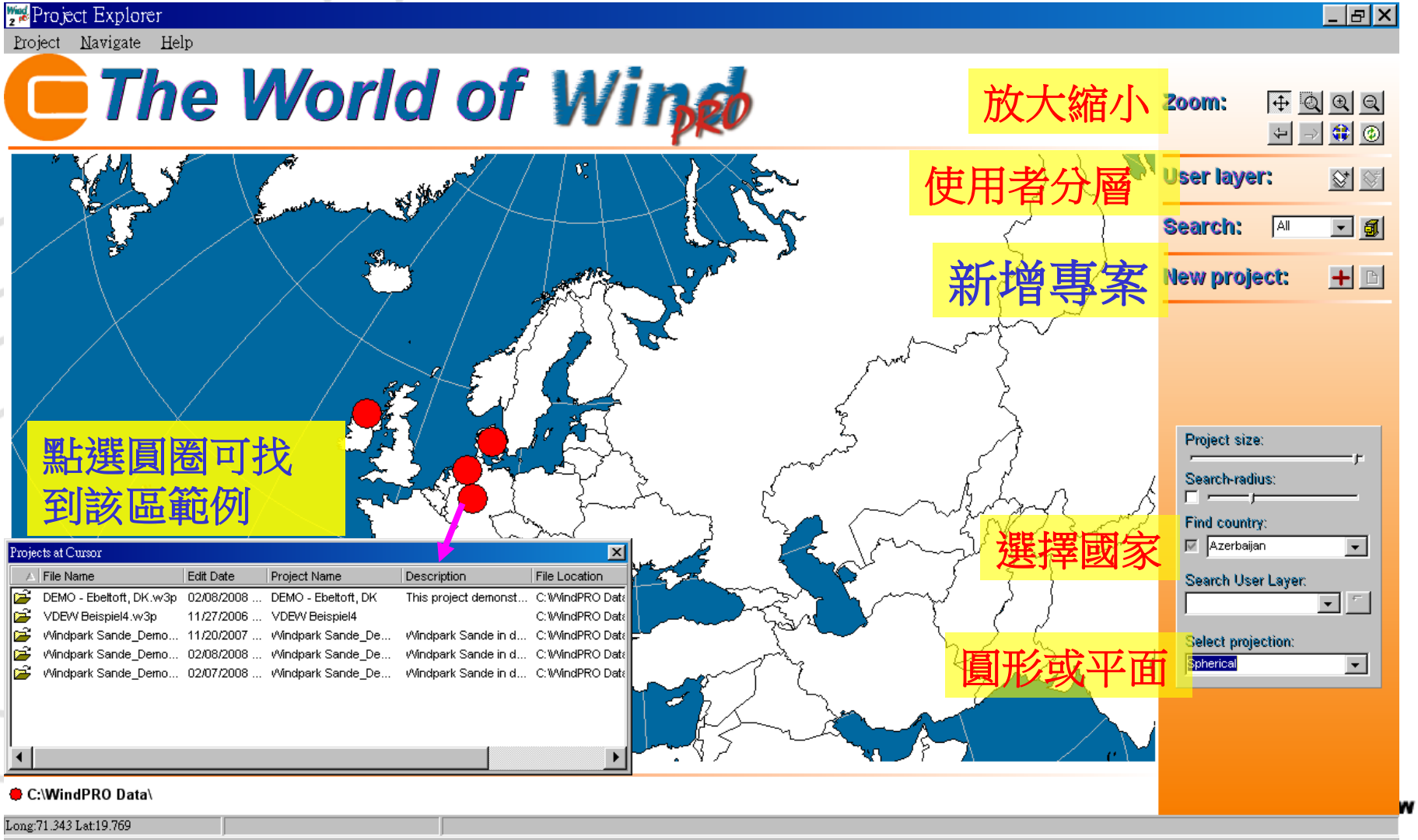
可計算的參數

產生的能源
噪音
功率損失

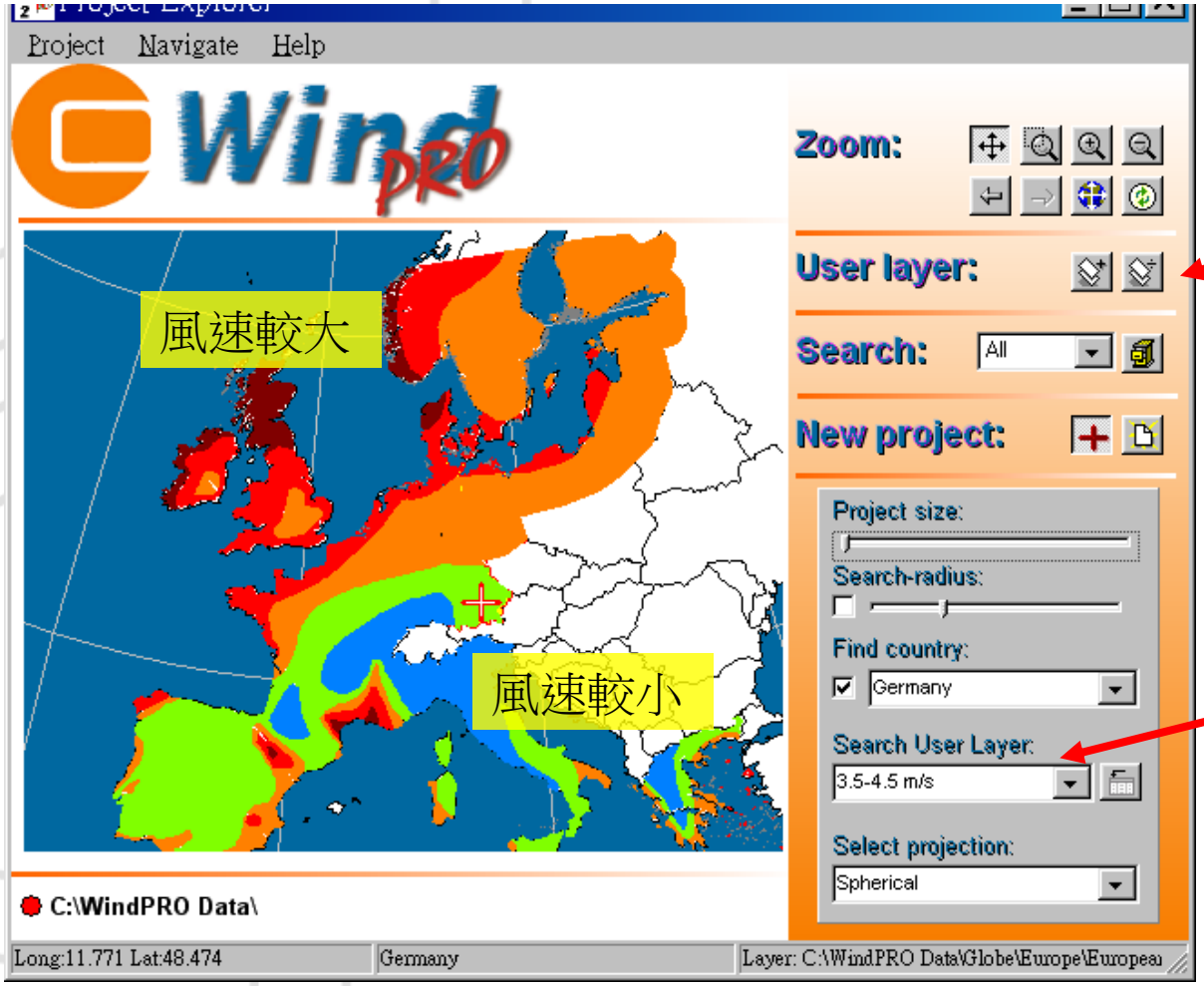
報表

印出資料報表

專案管理介面


Project Explorer
Project Navigate Help
The World of Wind PRO
放大縮小
Zoom:
使用者分層
User layer:
Search:
All
新增專案
New project:
點選圓圈可找到該區範例
Projects at Cursor
File Name
Edit Date
Project Name
Description
File Location
DEMO - Ebeltoft, DK.w3p 02/08/2008 ... DEMO - Ebeltoft, DK This project demonst... C:\WindPRO Data
VDEW Beispiel4.w3p 11/27/2006 ... VDEW Beispiel4 C:\WindPRO Data
Windpark Sande_Demo... 11/20/2007 ... Windpark Sande_De... Windpark Sande in d... C:\WindPRO Data
Windpark Sande_Demo... 02/08/2008 ... Windpark Sande_De... Windpark Sande in d... C:\WindPRO Data
Windpark Sande_Demo... 02/07/2008 ... Windpark Sande_De... Windpark Sande in d... C:\WindPRO Data
選擇國家
Project size:
Search-radius:
Find country:
Azerbaijan
Search User Layer:
圓形或平面
Select projection:
Spherical
C:\WindPRO Data\
Long:71.343 Lat:19.769

專案管理介面



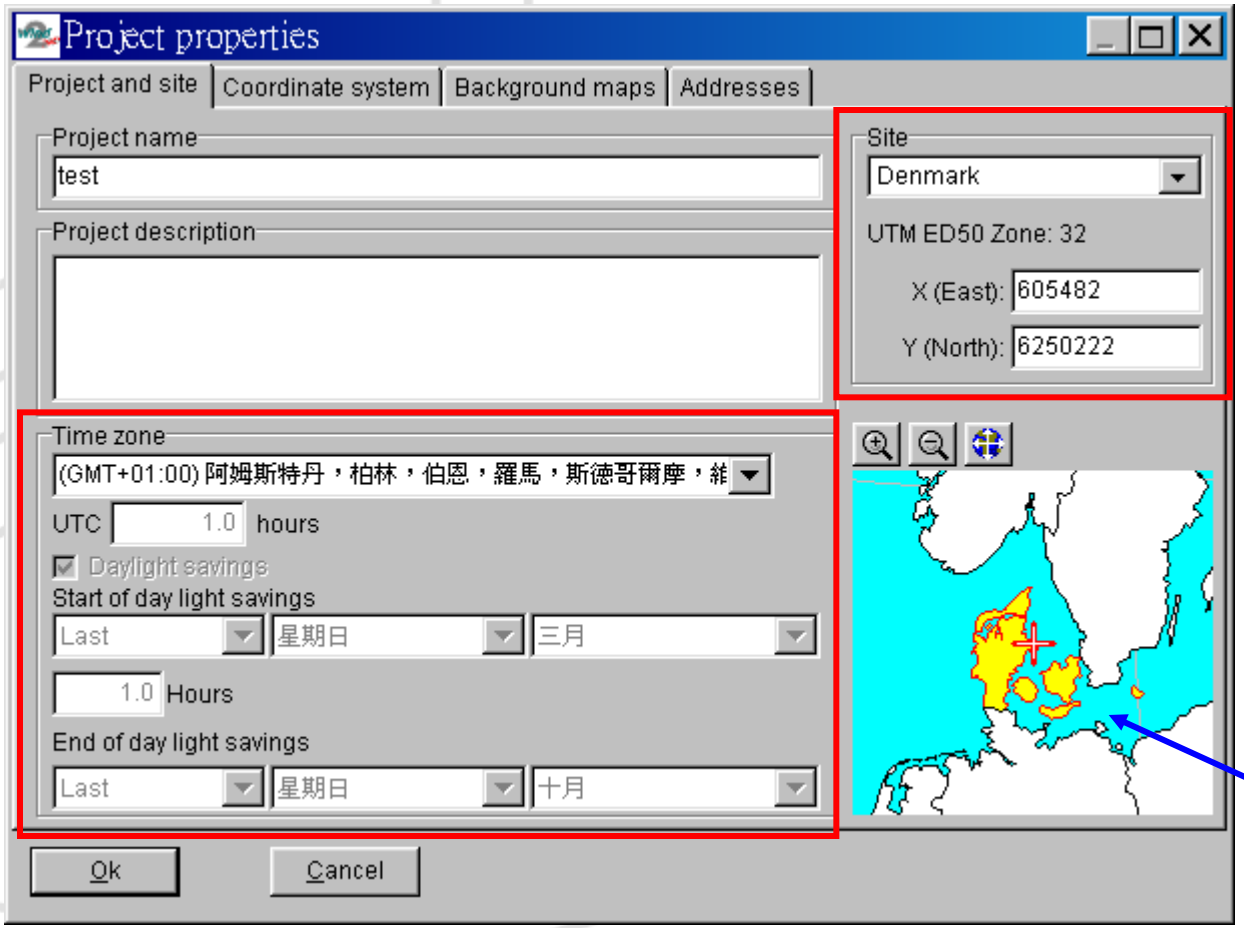
C:\WindPRO Data\Globe\Europe\EuropeanWindAtlas.shp

加到User Layer中

Wind Atlas
基本風能分布:
包含某地圖區域內的風速、風向

之後可看到風速分佈

專案設定介面

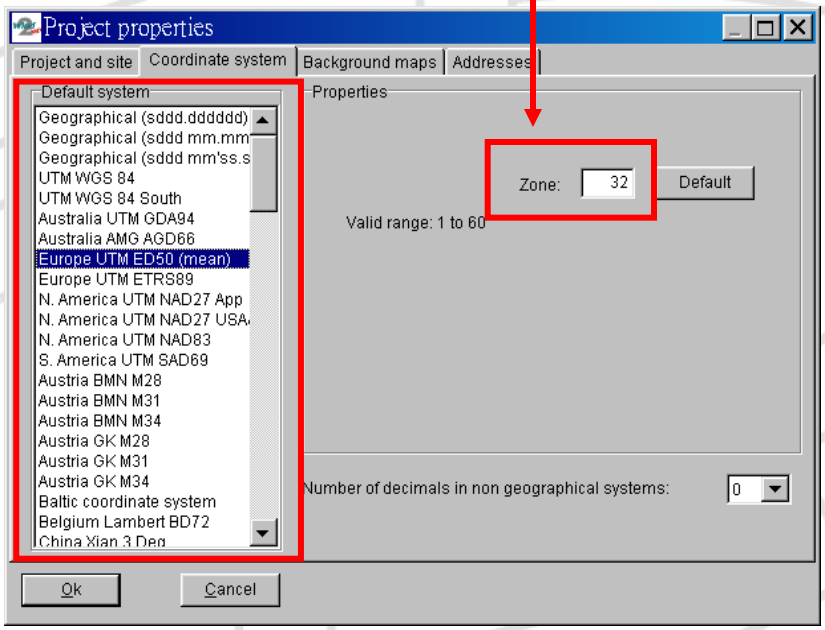


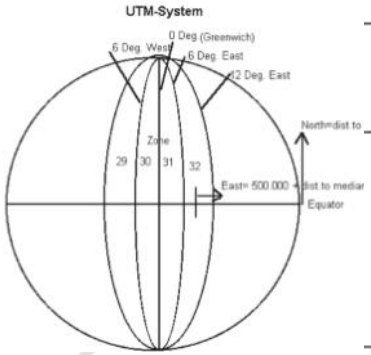
包含國家名稱、時區(考慮日照與日光節省時間)與緯度設定

可調整地區設定

專案設定介面

- 根據UTM坐標，地球分成60帶，每6度為一帶(平均長度500km,最大長度約667km)
- 台灣(121)約在51區,澎湖在50區





Overwiev of Longitudes and UTM-zones

Western longitude (West of Greenwich)			Eastern longitude (East of Greenwich)		
From	To	UTM-Zone	From	To	UTM-Zone
180	174	1	0	6	31
174	168	2	6	12	32
168	162	3	12	18	33
162	156	4	18	24	34
156	150	5	24	30	35
150	144	6	30	36	36
144	138	7	36	42	37
138	132	8	42	48	38
132	126	9	48	54	39
126	120	10	54	60	40
120	114	11	60	66	41
114	108	12	66	72	42
108	102	13	72	78	43
102	96	14	78	84	44
96	90	15	84	90	45
90	84	16	90	96	46
84	78	17	96	102	47
78	72	18	102	108	48
72	66	19	108	114	49
66	60	20	114	120	50
60	54	21	120	126	51
54	48	22	126	132	52
48	42	23	132	138	53
42	36	24	138	144	54
36	30	25	144	150	55
30	24	26	150	156	56
24	18	27	156	162	57
18	12	28	162	168	58
12	6	29	168	174	59
6	0	30	174	180	60

*WGS 84 = World Geographic System, the "New" world standard since 1984.
*ED 50 = European Datum since 1950 = Hayfort
*NAD = North American Datum (More variants)
*SAD = South American Datum

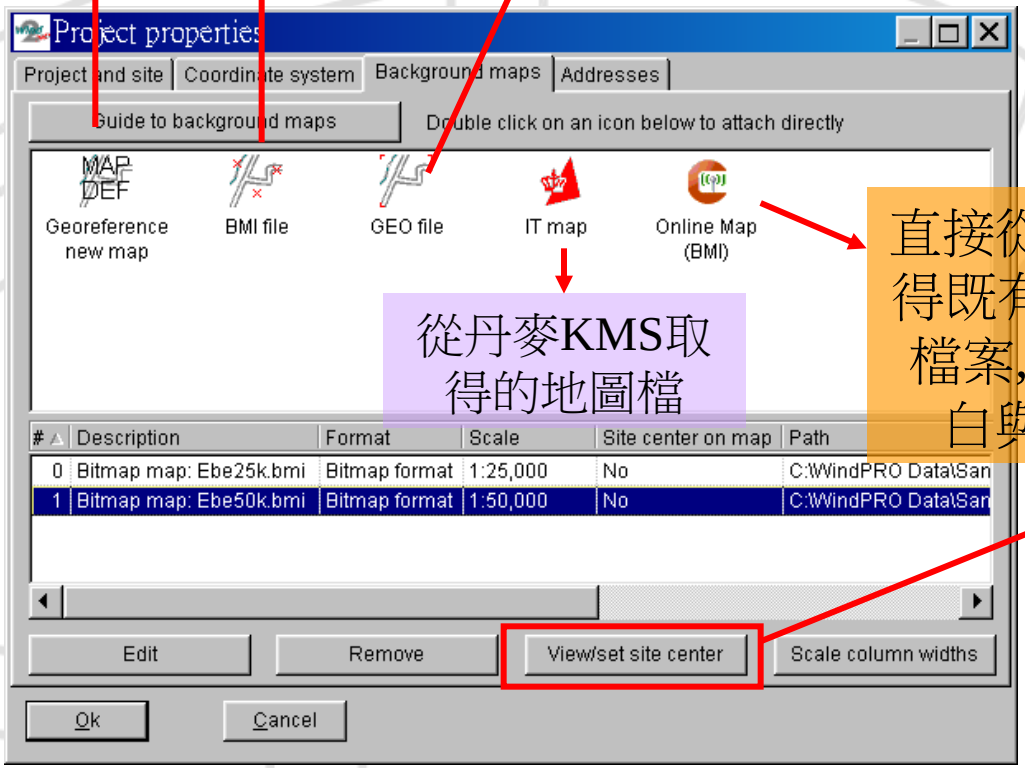
專案設定介面

讀bmp檔,無座標資訊, 可修圖,旋轉存成BMI檔

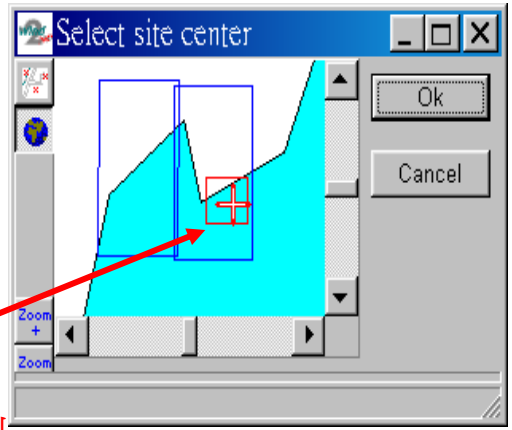
Windpro可處理的BMI檔

須包含座標資訊, 需為ESRI的格式, 若為tiff檔會包含.tfw的說明檔

- 僅有不同比例尺問題, 主要用來協助佈置風電廠節點
- 背景資料需搭配經緯度或經過裁減



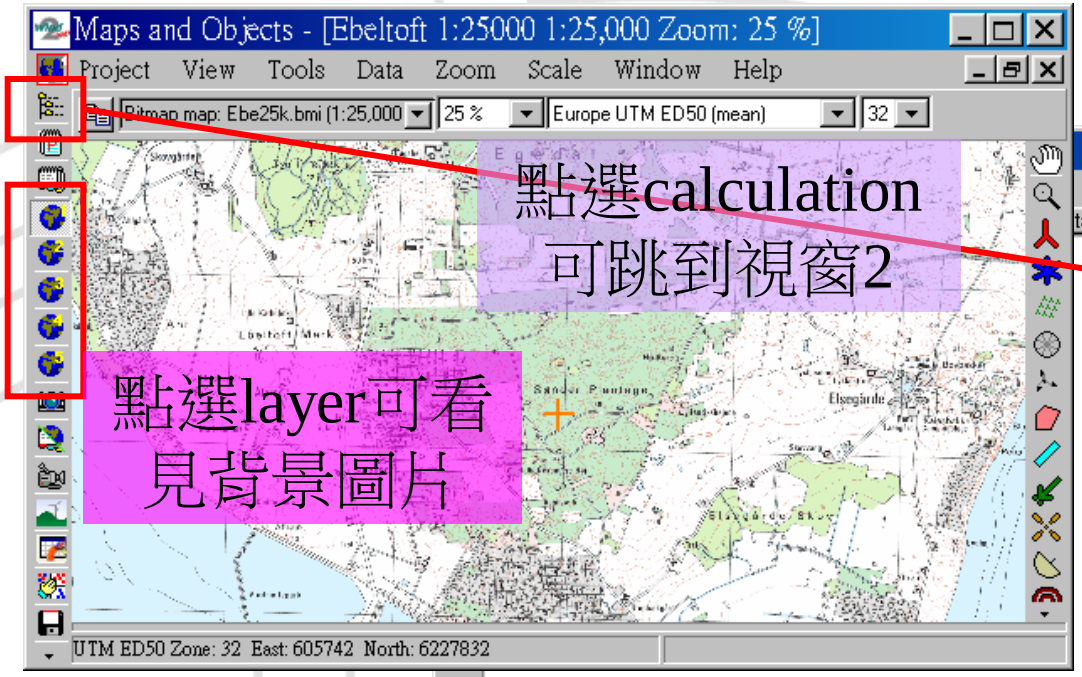
直接從線上取得既有的BMI檔案,可選黑白與彩色



兩地圖分別設定中心點

軟體操作介面

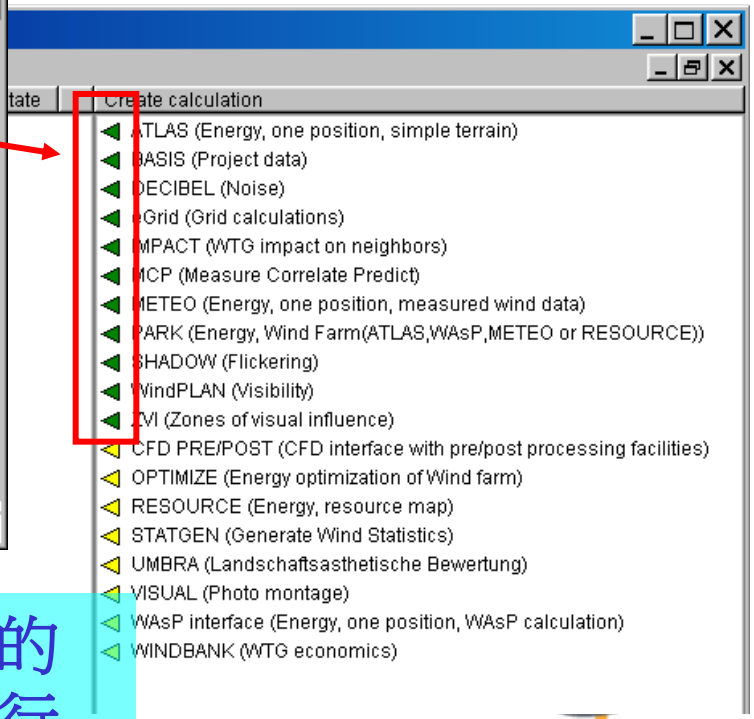
視窗1. 風電廠建置
Maps &Objects



點選calculation
可跳到視窗2

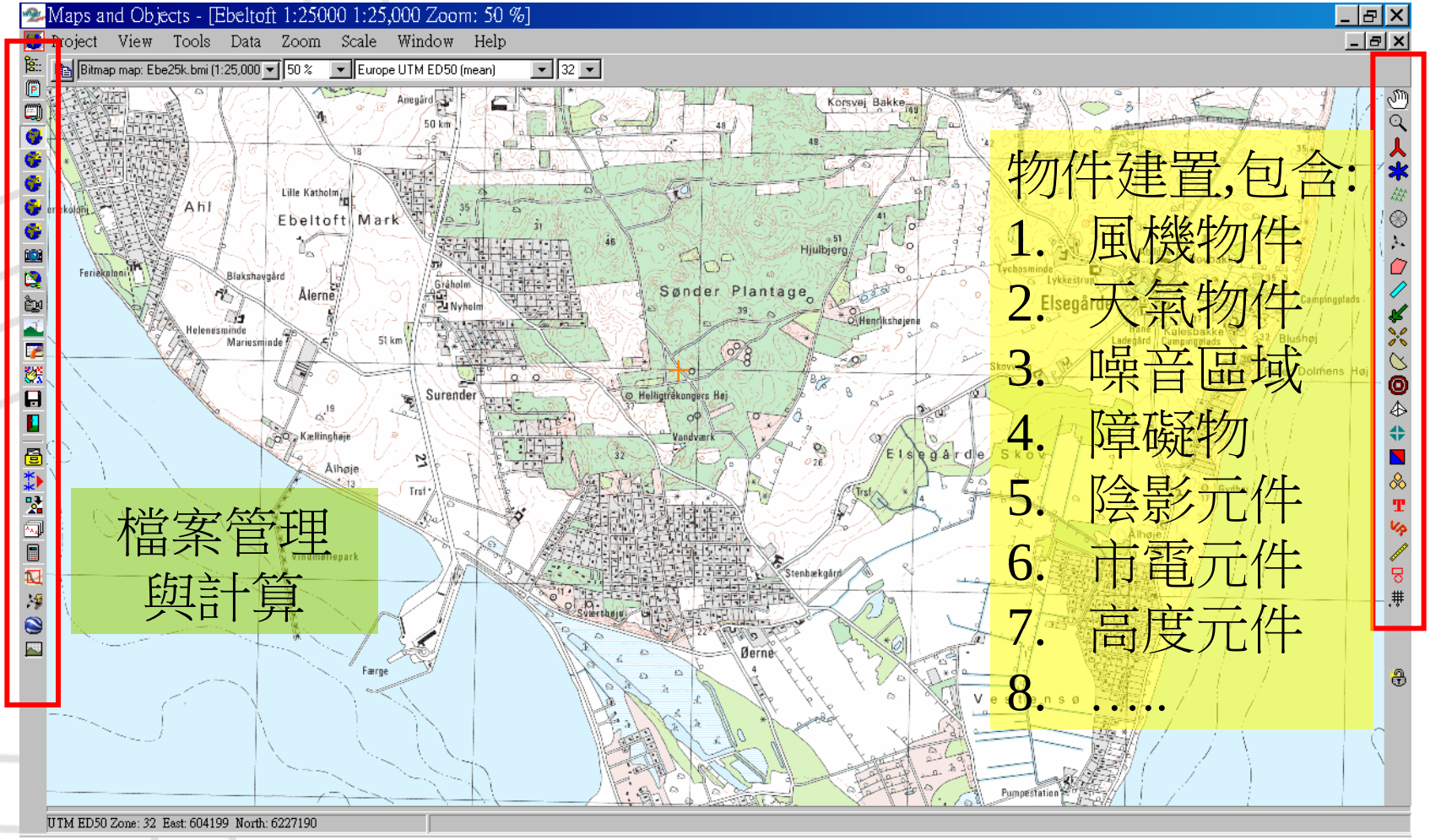
點選layer可看
見背景圖片

視窗2. 計算參數
Calculation

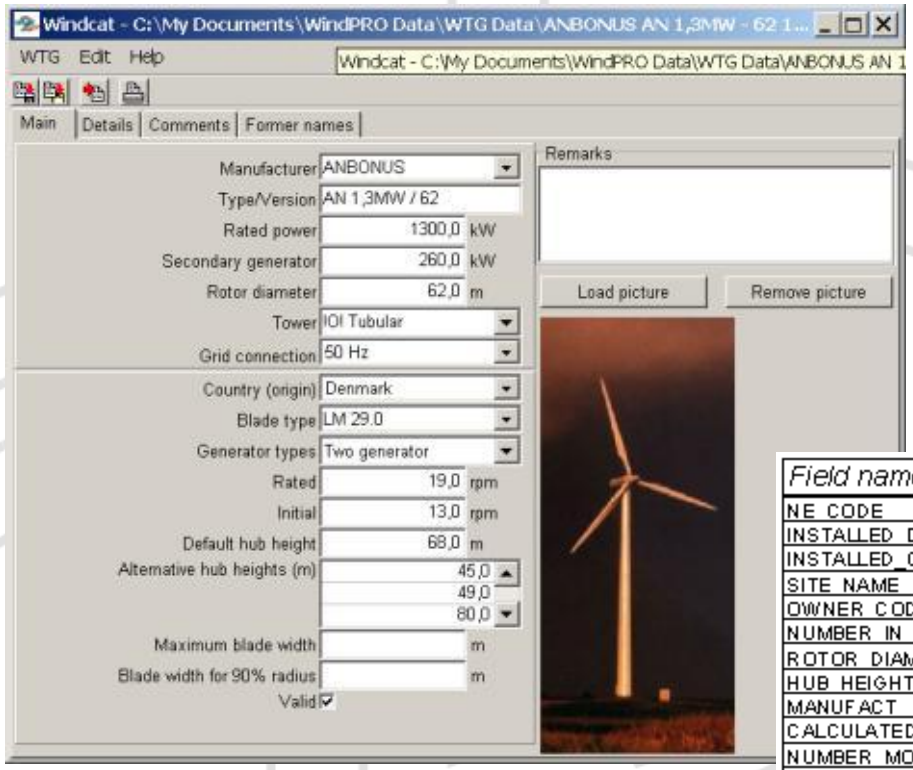


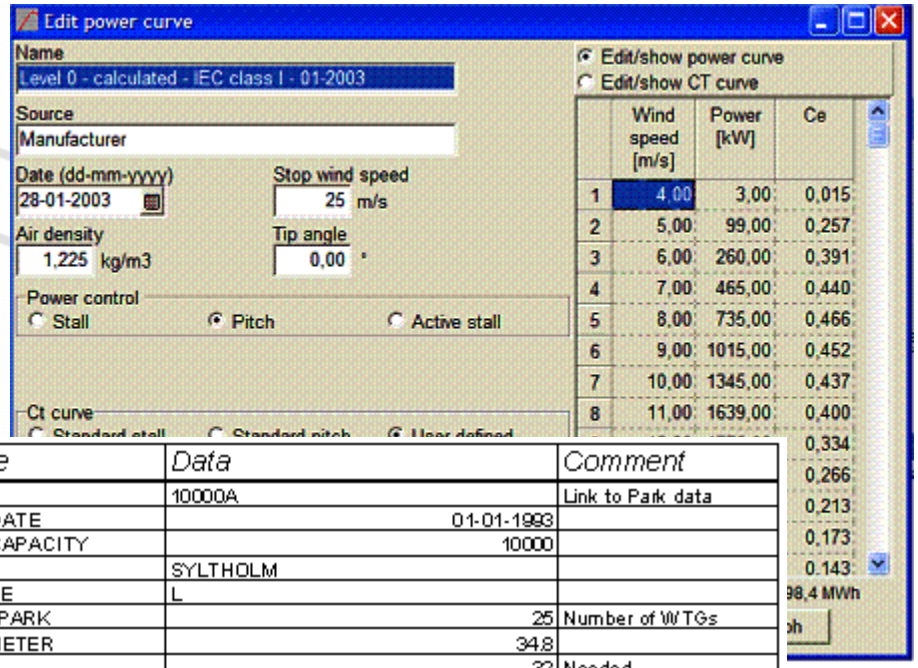
綠色為可執行的
黃色為不可執行

Maps & Objects



風力發電機模型



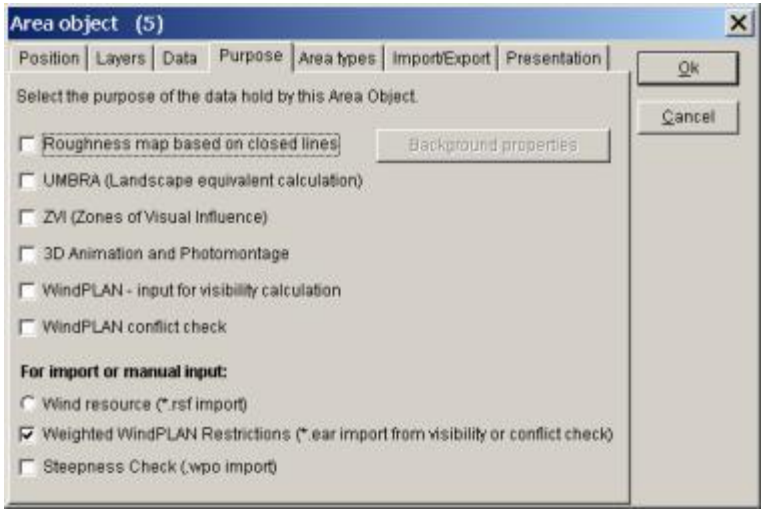


Field name	Data	Comment
NE_CODE	10000A	Link to Park data
INSTALLED_DATE	01-01-1993	
INSTALLED_CAPACITY	10000	
SITE_NAME	SYLTHOLM	
OWNER_CODE	L	
NUMBER_IN_PARK	25	Number of WTGs
ROTOR_DIAMETER	34.8	
HUB_HEIGHT	32	Needed
MANUFACT	DVT	
CALCULATED_PROD	0	
NUMBER_MONTHS_NE	62	Months with production
NUMBER_MONTHS_DMI	0	
WCP_NE	19549749.09	Actual production
WCP_DMI	0	
END_DATE	01-09-1998	No longer existing
WTG_ID	DVT ; ; 400/ 0; 34.8;!O!	WTG-Type and kW
PARK_EFFICIENCY	1	
UTM_ZONE	32	Needed
UTM_EAST	654797	Needed
UTM_NORTH	6057428	Needed
UTM_PREC	P	
KOMMUNE_NR	383	Region
PARKNAME	SYLTHOLM	

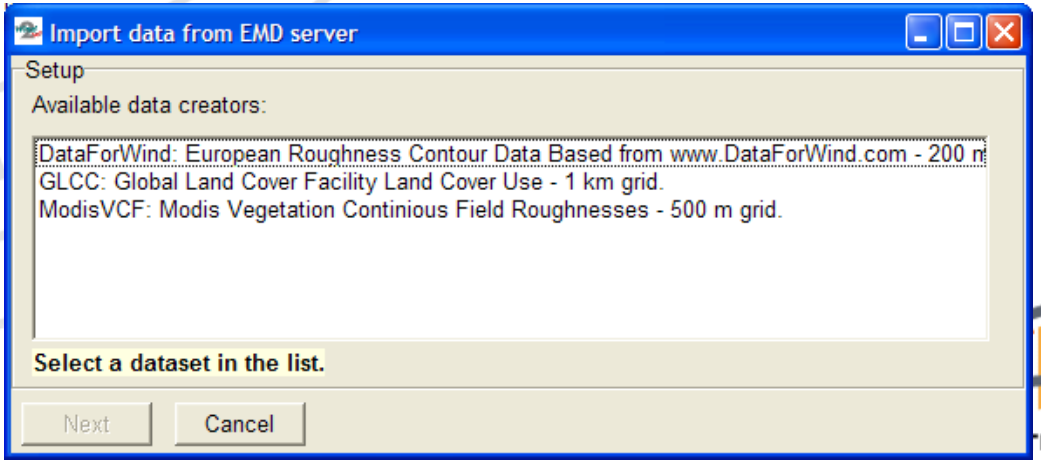
可從外部輸入

區域物件

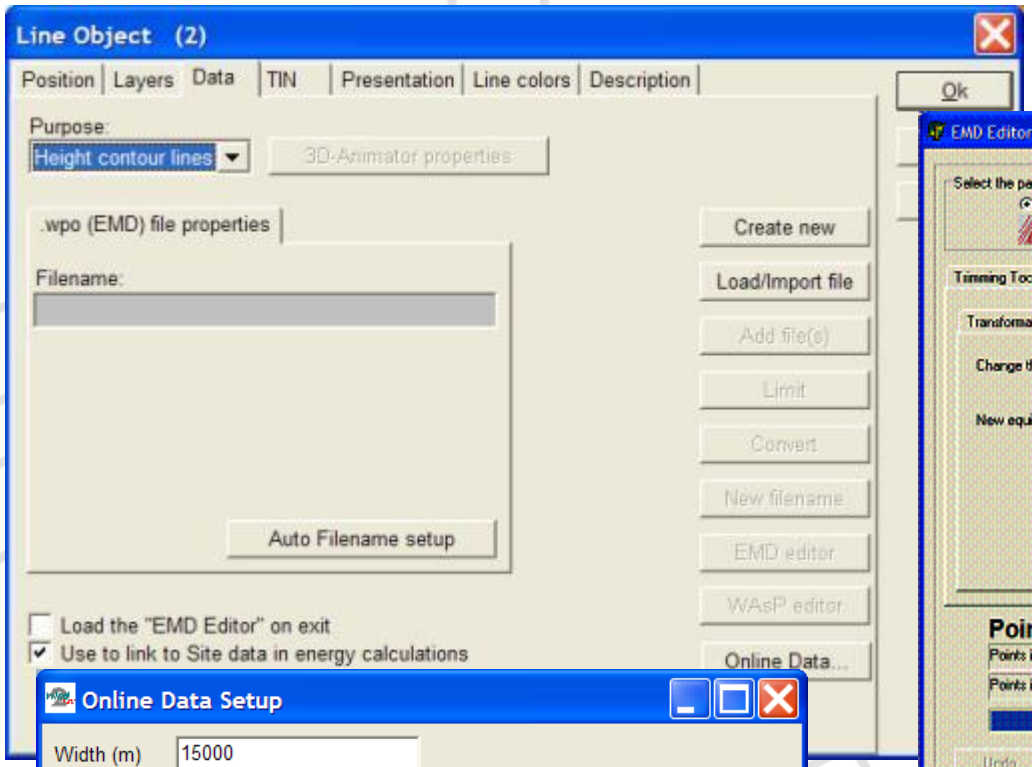
- Roughness areas *
- UMBRA (German landscape evaluation model)
- ZVI (Zones of Visual Influence)
- Visibility calculation (WindPLAN)
- WindPLAN (conflict check)
- WindPLAN (restrictions for weighted WindPLAN)
- Wind resources in planning
- 3D animation and photomontage (data is used as input for visualization of artificial landscape.)
- Steepness regions

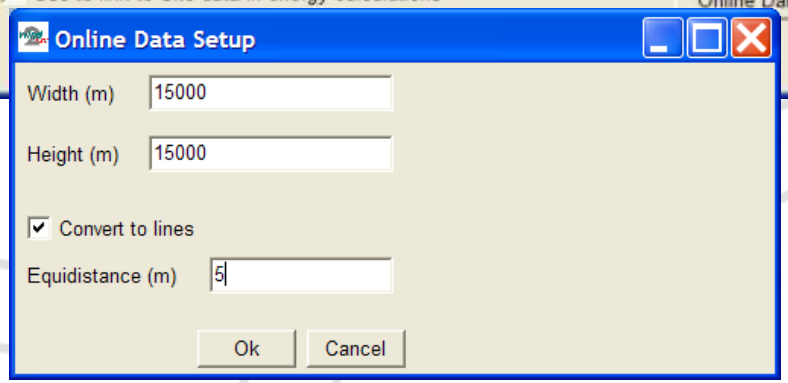


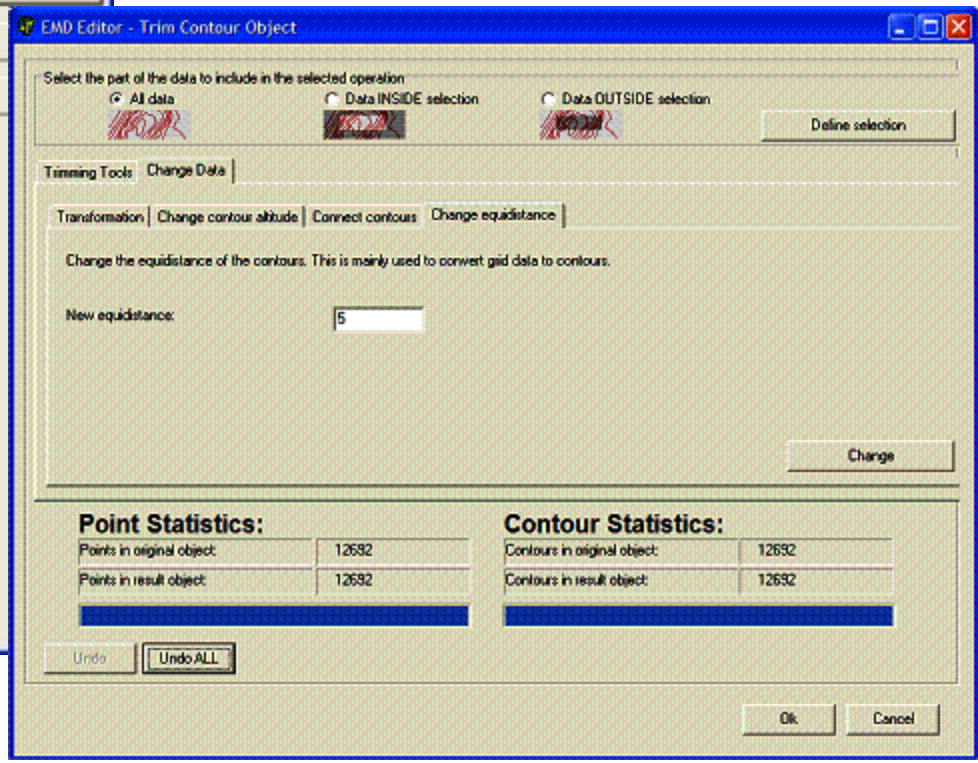
支援外部輸入



高度建立

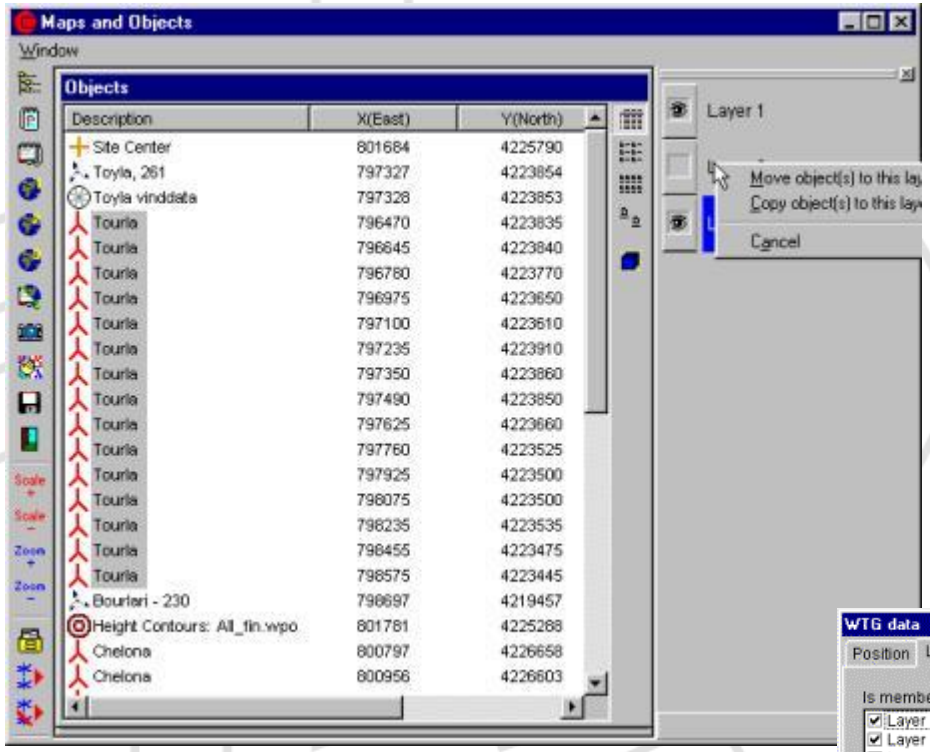

Line Object (2)
Position
Layers
Data
TIN
Presentation
Line colors
Description
Ok
Purpose:
Height contour lines
3D-Animator properties
.wpo (EMD) file properties
Filename:
Create new
Load/Import file
Add file(s)
Limit
Convert
New filename
EMD editor
WAsP editor
Online Data...
Auto Filename setup
Load the "EMD Editor" on exit
Use to link to Site data in energy calculations

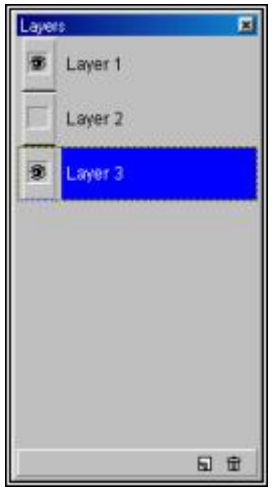

Online Data Setup
Width (m)
15000
Height (m)
15000
Convert to lines
Equidistance (m)
5
Ok
Cancel

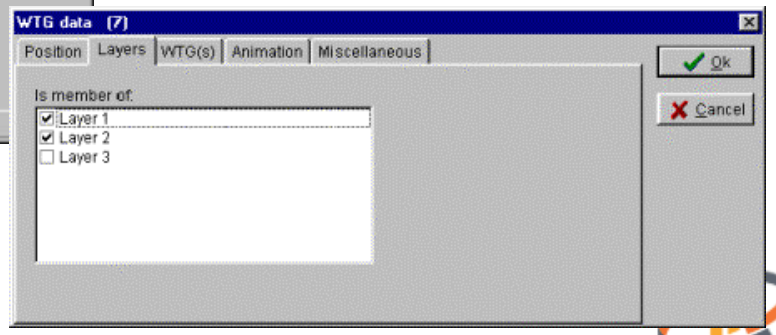

EMD Editor - Trim Contour Object
Select the part of the data to include in the selected operation
All data
Data INSIDE selection
Data OUTSIDE selection
Define selection
Trimming Tools
Change Data
Transformation
Change contour altitude
Connect contours
Change equidistance
Change the equidistance of the contours. This is mainly used to convert grid data to contours.
New equidistance:
5
Change
Point Statistics:
Points in original object:
12692
Points in result object:
12692
Contour Statistics:
Contours in original object:
12692
Contours in result object:
12692
Undo
Undo ALL
Ok
Cancel


MICRODEM / Terra Base II 6.0 alpha
File
Analyze
StereoNet
GPS
Options
Open DEM
Open Image

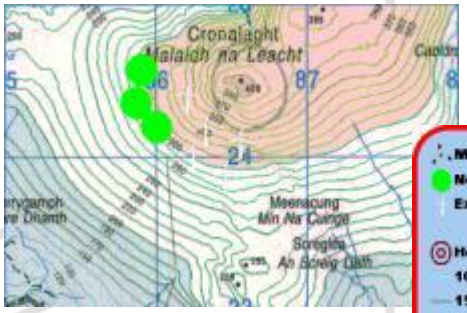
分層架構


Maps and Objects
Window
Objects
Description
X(East)
Y(North)
Site Center 801684 4225790
Toyla, 261 797327 4223854
Toyla vinddata 797328 4223853
Tourla 796470 4223835
Tourla 796645 4223840
Tourla 796780 4223770
Tourla 796975 4223650
Tourla 797100 4223610
Tourla 797235 4223910
Tourla 797350 4223860
Tourla 797490 4223850
Tourla 797625 4223660
Tourla 797760 4223525
Tourla 797925 4223500
Tourla 798075 4223500
Tourla 798235 4223535
Tourla 798455 4223475
Tourla 798575 4223445
Bourlari - 230 798697 4219457
Height Contours: All_fin.wpo 801781 4225288
Chelona 800797 4226658
Chelona 800956 4226603
Layer 1
Move object(s) to this la
Copy object(s) to this lay
Cancel

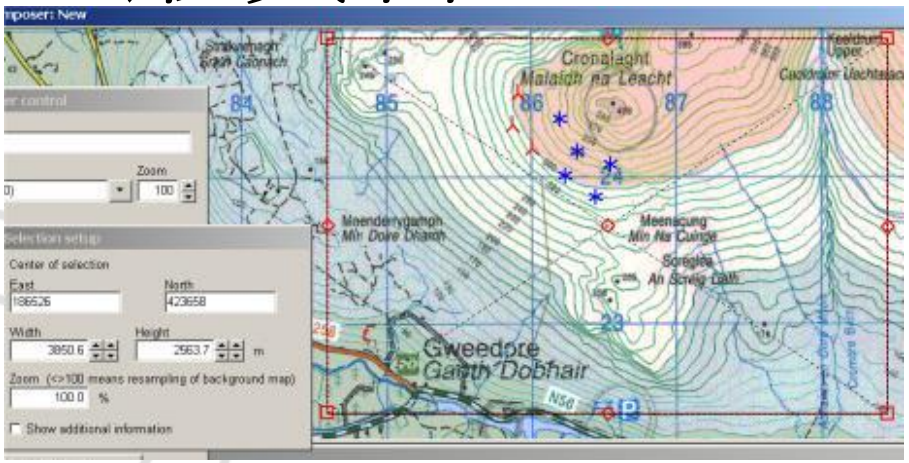

Layers
Layer 1
Layer 2
Layer 3

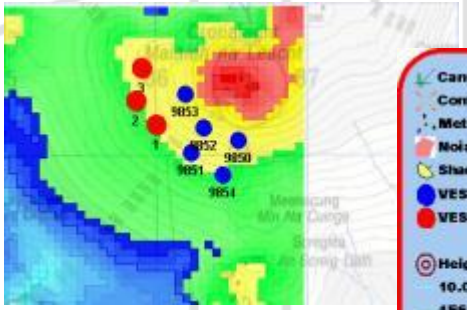

WTG data (7)
Position
Layers
WTG(s)
Animation
Miscellaneous
Ok
Cancel
Is member of:
Layer 1
Layer 2
Layer 3

地圖與地形資料

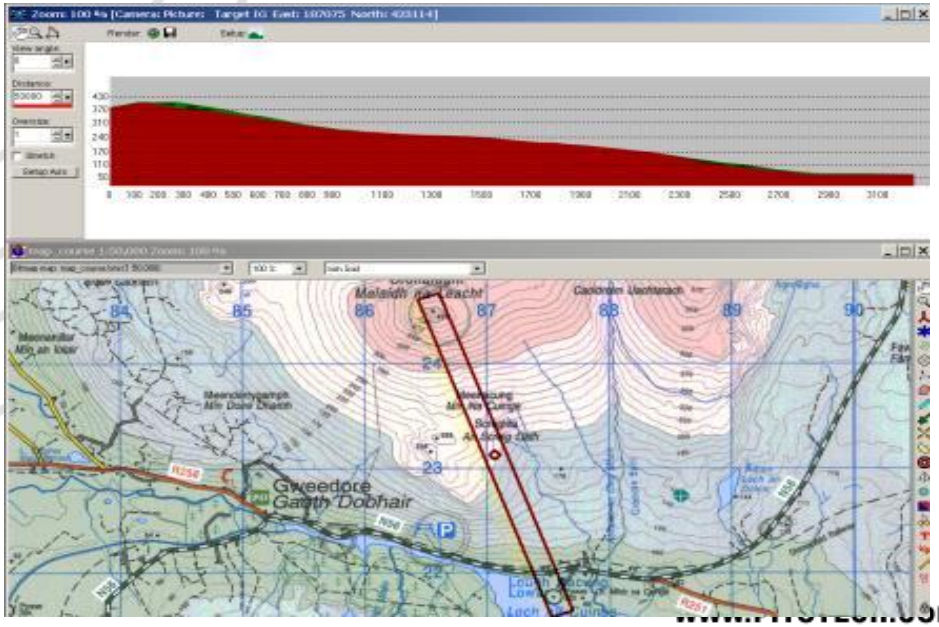

Cronalaght
Malaidh na Leacht
Meenacung
Min Na Cuinge
Sceiglea
An Sceig Liath


Meteorological Data
New WTG
Existing WTG
Height Contours: Heightcontour.wpo
10.0 - 156.0
156.0 - 302.0
302.0 - 448.0
448.0 - 594.0
594.0 - 740.0


Cronalaght
Malaidh na Leacht
Meenacung
Min Na Cuinge
Sceiglea
An Sceig Liath
Gweedore
Gaoth Dobhair
Zoom
Center of selection
East
North
Width
Height
Show additional information

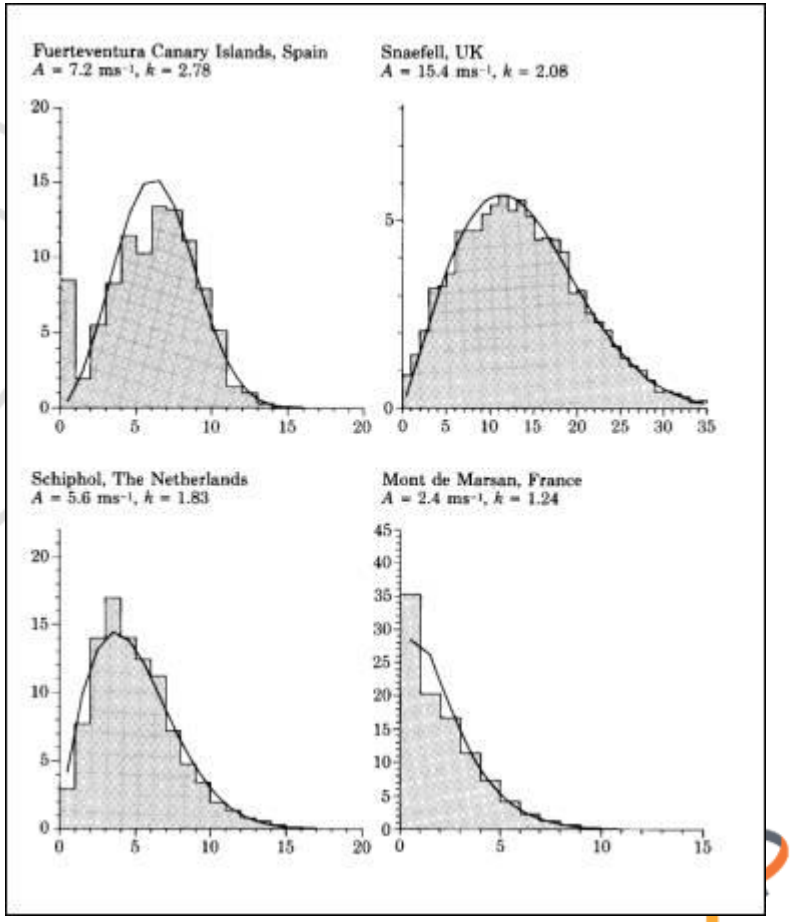

9853
9852
9850
9851
9854


Camera
Control Point
Meteorological Data
Noise Sensitive Area
Shadow Receptor
VESTAS V39 600 39.0 !O!
VESTAS V47 660 47.0 !O!
Height Contours: Heightcontour.wpo
10.0 - 156.0
156.0 - 302.0
302.0 - 448.0
448.0 - 594.0
594.0 - 740.0
Result Layer
Area object (ZVI): ZVI-Cronalaght.wr2r
Forest
Village
Water


Cronalaght
Malaidh na Leacht
Meenacung
Min Na Cuinge
Sceiglea
An Sceig Liath
Gweedore
Gaoth Dobhair

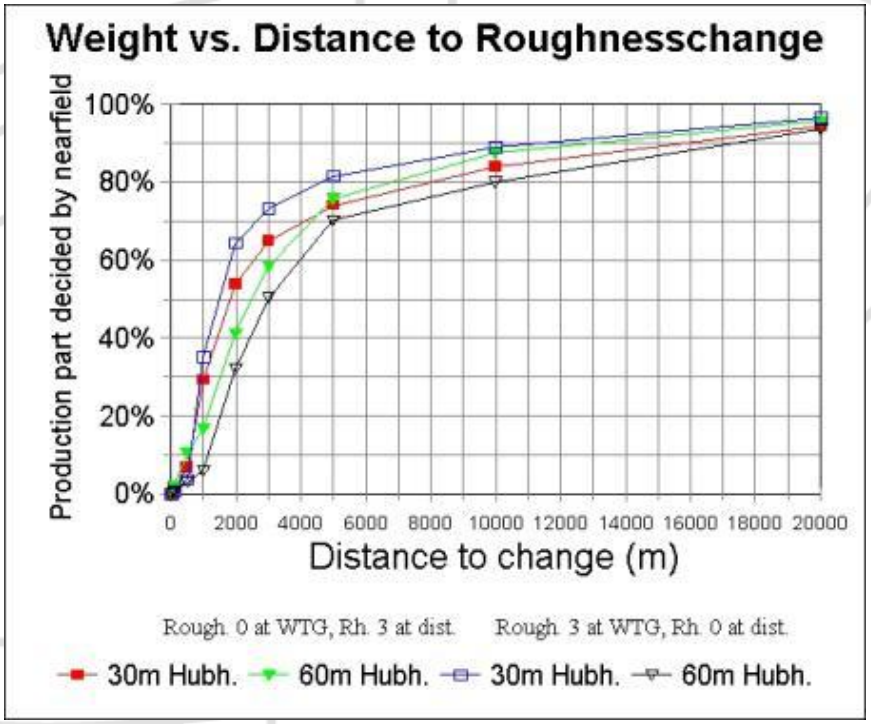
風速特性

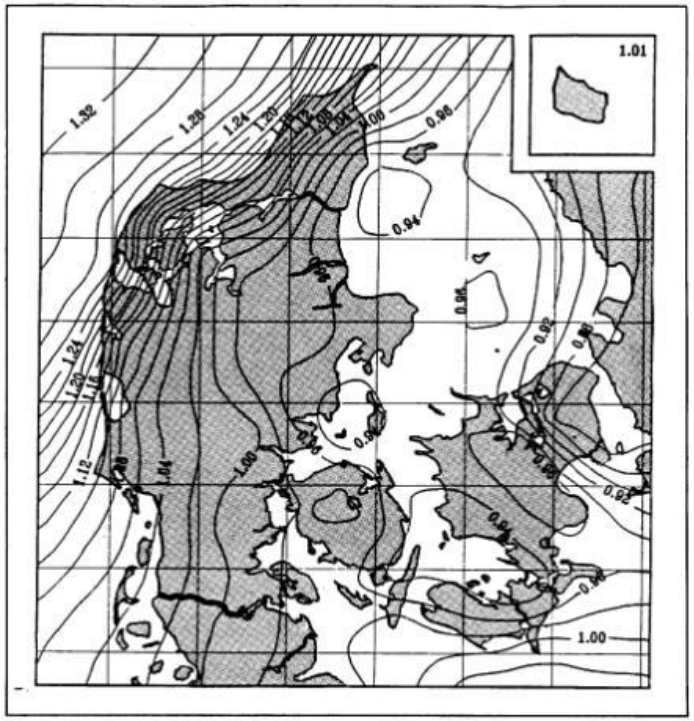
- 風速分布與hub高度有關
- 風機的功率曲線特性
- Meteo氣象資料



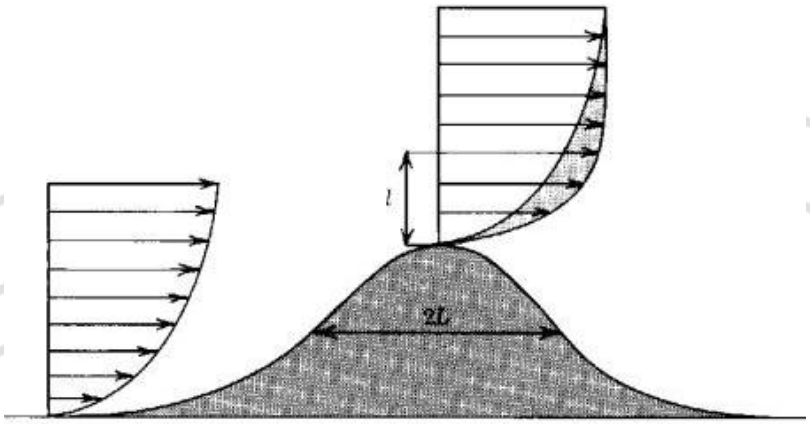
風能計算模組

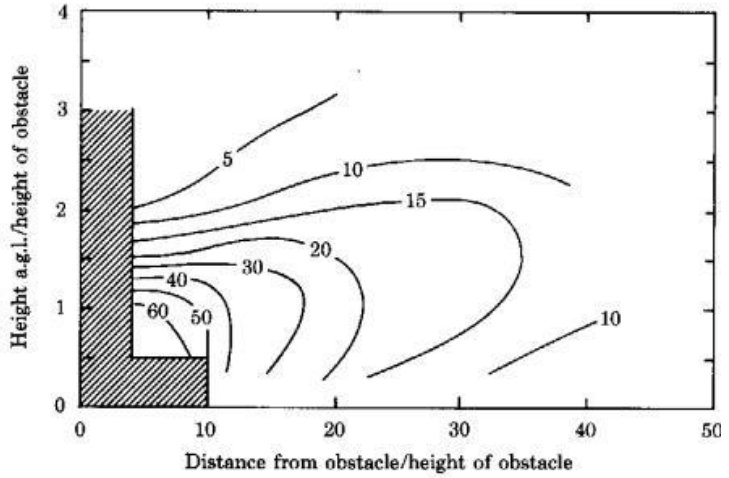
- Wind atlas 風能分布方法(模組: ATLAS, WAsP Interface and RESOURCE)
- 直接使用量測方法 (模組: METEO使用Weibull或量測選項)
- PARK – 整合上述方法運用到風能計算中

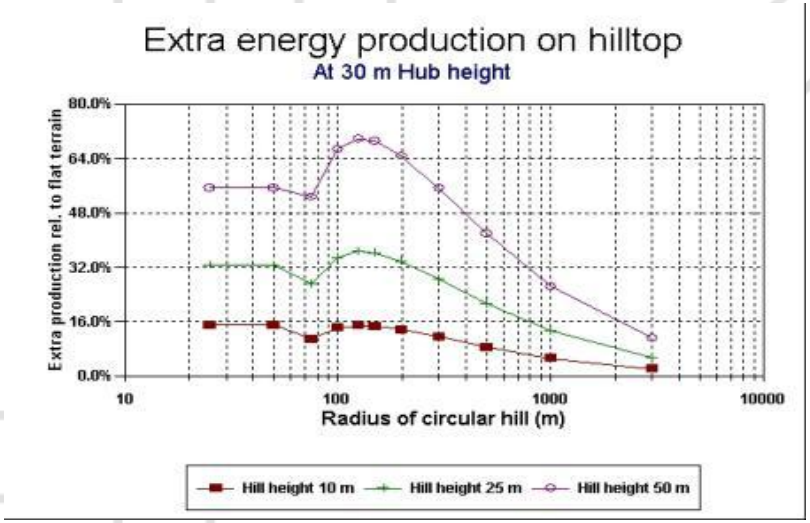


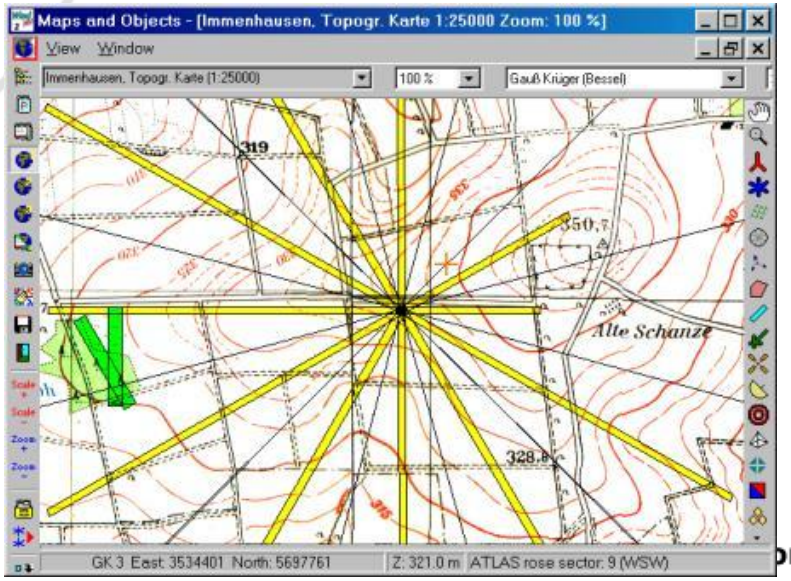


風資源地圖模型

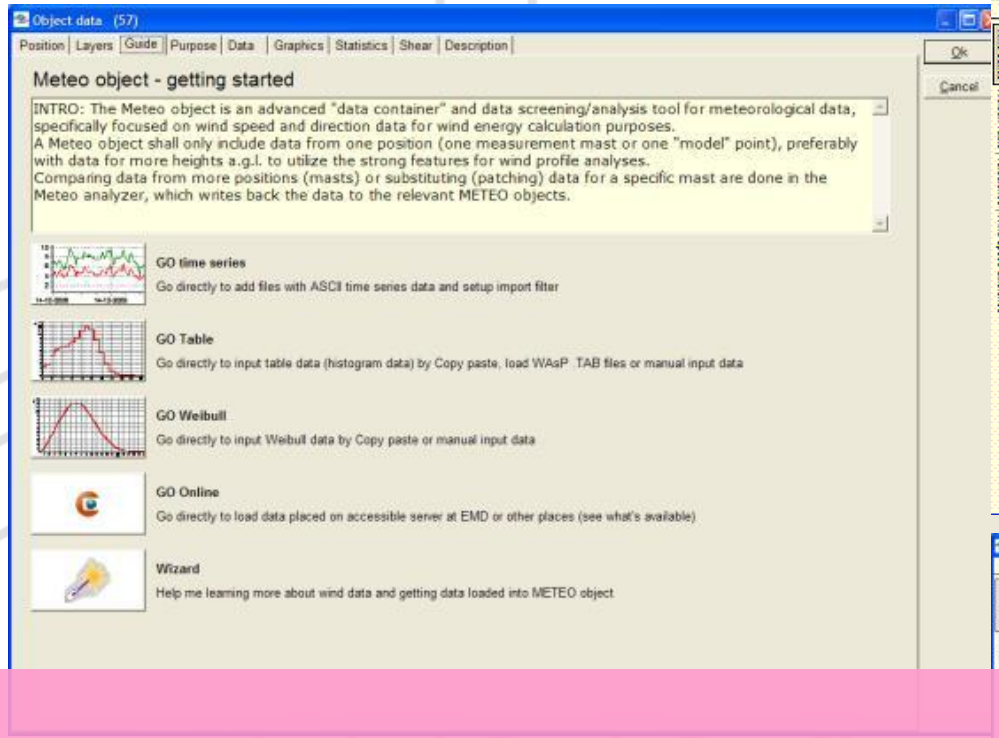

l
2L

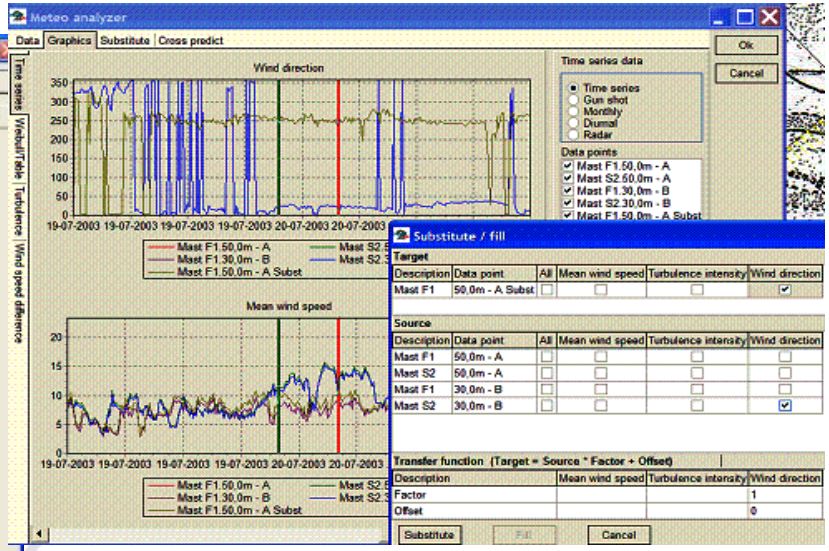

Height a.g.l./height of obstacle
Distance from obstacle/height of obstacle
0
1
2
3
4
10
20
30
40
50
5
10
15
20
30
40
60
50
10

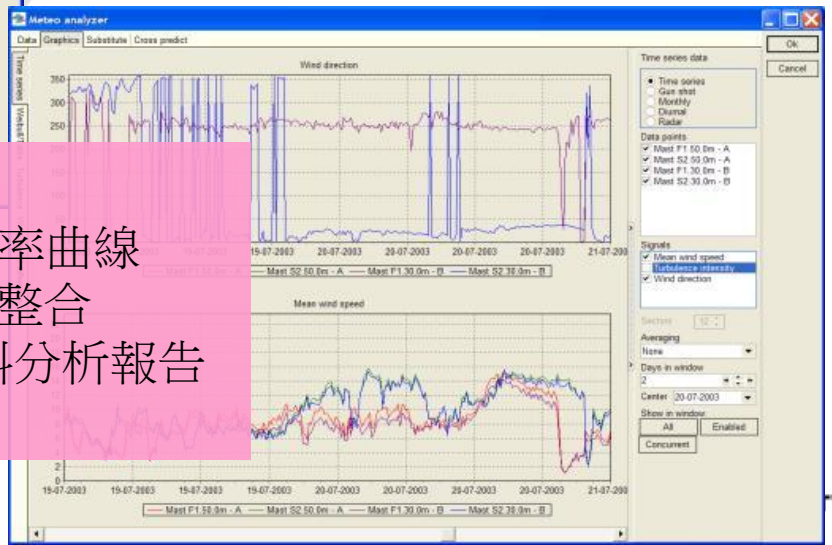

Extra energy production on hilltop
At 30 m Hub height
Extra production rel. to flat terrain
80.0%
64.0%
48.0%
32.0%
16.0%
0.0%
10
100
1000
10000
Radius of circular hill (m)
Hill height 10 m
Hill height 25 m
Hill height 50 m


Maps and Objects - [Immenhausen, Topogr. Karte 1:25000 Zoom: 100 %]
View Window
Immenhausen, Topogr. Karte (1:25000)
100 %
Gauß Krüger (Bessel)
319
350,7
Alte Schanze
328,6
GK 3 East: 3534401 North: 5697761
Z: 321.0 m
ATLAS rose sector: 9 (WSW)

氣象物件







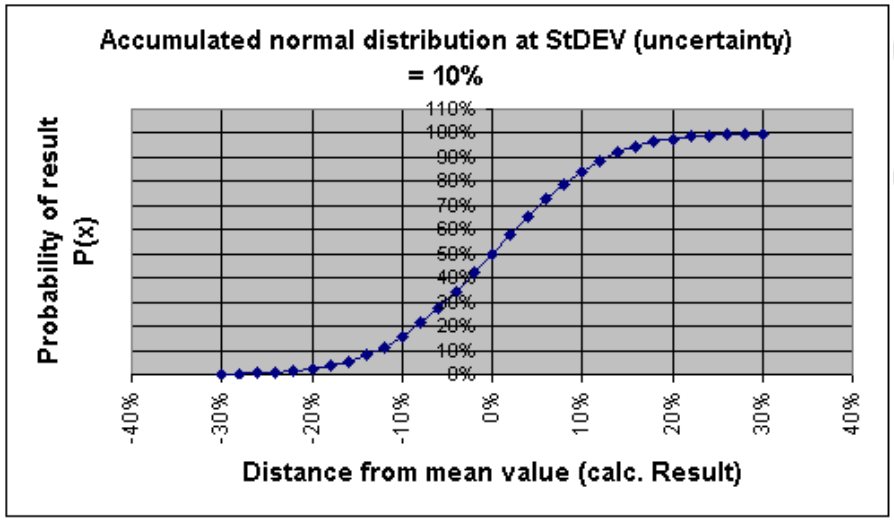
提供韋伯方法 (Weibull)和至風力發電機的功率曲線
使用量測方法，風力資料直接與功率曲線整合
產生發電量分析報告、功率曲線報告、風力資料分析報告

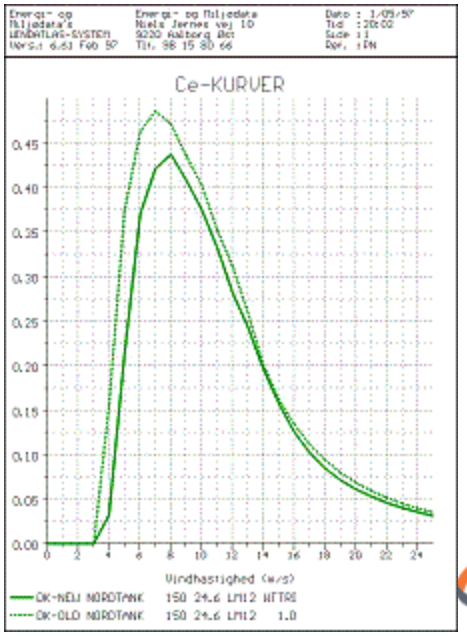
損失

- **Grid** – (可透過eGRID模組計算). 因曲線是在通過變壓器前量測的，因此找出變壓器中的功率損失是很重要的工作
- **Availability** – 依據製造商所提供的資料，WTG差不多有3%的損耗。某些國家市電的停擺時間很普遍，損失或者更高。但大部分的工業國家來說，市電的可獲得率基本上可看成100%.
- **Blade degradation and icing** – 葉片分析
- **High-wind hysteresis** – 若風速高於截止速度(每年至少一次)，則距離風機再次運作則需要一段時間, 但這段時間並未包含在產能計算, 須手動扣除。在丹麥，每次停止約有0.3%的能源產生損耗(粗略估計)
- **Operation mode losses** – 風機可針對不同參考因素下運作,如: turbulence (closely-spaced WTGs stopped in certain wind directions), flicker (during hours when the nearest neighbors experience significant flicker) or noise reduced mode (e.g. during night time).

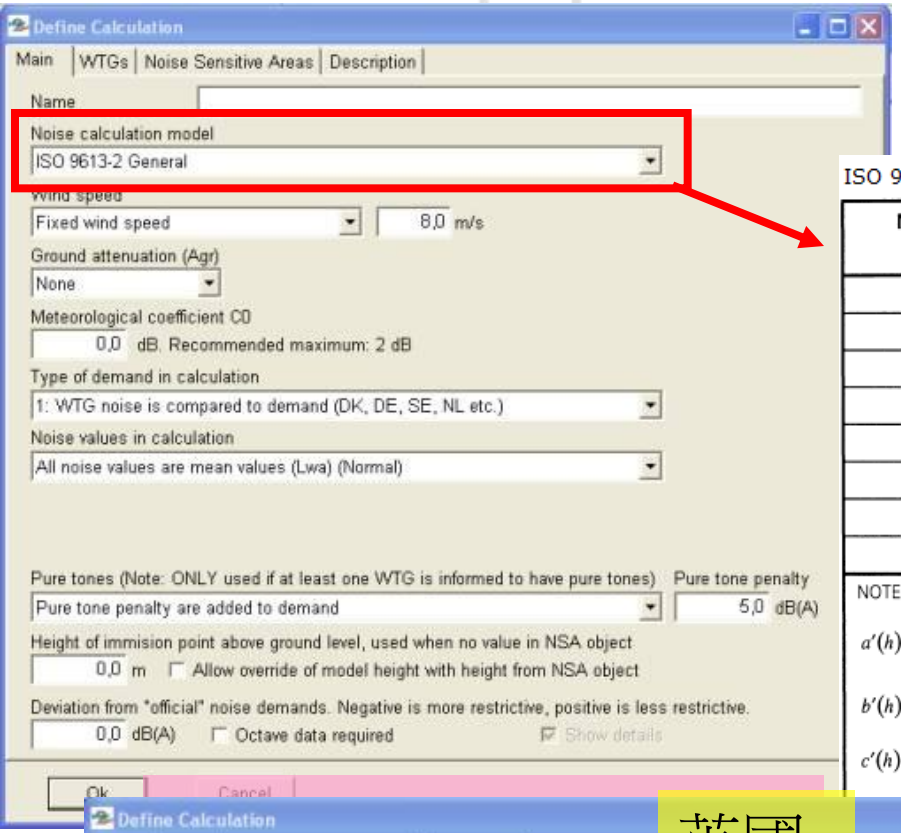
風能計算的不確定性

- The Wind Statistics (5%)
- The Terrain Description, i.e. roughness, hills and obstacles (5%)
- The Power Curve (5% if verified, see Section 5.2)
- The calculation method (5% for normal, not too-complex terrain)

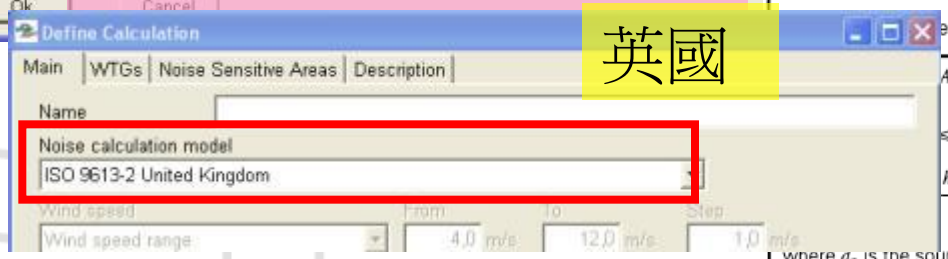




噪音模組



選擇噪音計算模型



英國

ISO 9613-2 document explains how the three ground attenuations are calculated.

Nominal midband frequency Hz	A_s or A_r [1] dB	A_m dB
63	− 1,5	− 3q [2]
125	− 1,5 + $G \times a'(h)$	− 3q(1 − G_m)
250	− 1,5 + $G \times b'(h)$	
500	− 1,5 + $G \times c'(h)$	
1 000	− 1,5 + $G \times d(h)$	
2 000	− 1,5(1 − G)	
4 000	− 1,5(1 − G)	
8 000	− 1,5(1 − G)	

NOTES

$$a'(h) = 1{,}5 + 3{,}0 \times e^{-0{,}12(h-5)^2}\left(1 - e^{-d_p/50}\right) + 5{,}7 \times e^{-0{,}09h^2}\left(1 - e^{-2{,}8 \times 10^{-6} \times d_p^2}\right)$$

$$b'(h) = 1{,}5 + 8{,}6 \times e^{-0{,}09h^2}\left(1 - e^{-d_p/50}\right)$$

$$c'(h) = 1{,}5 + 14{,}0 \times e^{-0{,}46h^2}\left(1 - e^{-d_p/50}\right)$$

$$e^{-0{,}9h^2}\left(1 - e^{-d_p/50}\right)$$

A_s, take $G = G_s$ and $h = h_s$. For calculating A_r, take $G = G_r$ and $h = h_r$. See 7.3.1 for values of G for various

$\leq 30(h_s + h_r)$

$h_r)$ when $d_p > 30(h_s + h_r)$

where d_p is the source-to-receiver distance, in metres, projected onto the ground planes.

噪音模組

丹麥

DANISH RULES FOR NOISE CALCULATION.

The calculation is based on the "Bekendtgørelse nr. 1518 af 14. dec 2006" from the Danish Environmental Agency.

The noise impact from WTGs are not allowed to exceed the following limits: (Wind speeds in 10 m height)

1) At outdoor areas maximum 15 m from neighbor settlements in the open land.
   a) 44 db(A) at wind speed 8 m/s.
   b) 42 db(A) at wind speed 6 m/s.
2) At outdoor areas in residential or recreational areas.
   a) 39 db(A) at wind speed 8 m/s in residential areas.
   b) 37 db(A) at wind speed 6 m/s in residential areas.

If a WTG has pure tones in the noise emission, a penalty of 5 dB is added.

$L_{pA} = {}_{LWA,ref} - 10 \times \log(l^2 + h^2) - 8dB - \Delta L_a$

Where
l is the distance between the WTG and the neighbor
h is the height difference between the nacelle and the neighbor (normally = hub height) and

ΔL_a is the air absorption.

ΔL_a is calculated as $\alpha_a \sqrt{(l^2 + h^2)}$

Where α_a is the damping coefficient (0.005 dB/m or from the table below).

Octave Band Damping Coefficient:

Center freq. (Hz)≤	125	250	500	1000	2000	4000	8000
α_a (dB/m)	0	0	0.002	0.004	0.007	0.017	0.06

德國

German rule VDI 2714

$LS = LW + DI + KO - DS - DL - DBM - DD - DG$ in dB(A)

LS : Calculated noise level in distance S
LW : Noise emission for the WTG
DI : Directional impact figure (= 0)
KO : Solid angle figure (= 3 dB)
DS : Distance figure DS=10 log(4 π S2)
DL : Air absorption figure $DL=\alpha_L S$

$\alpha_L = 0.00209$ dB/m

DBM :Terrain and meteorological damping figure
DBM = Max(0, 4.8 - (hq+hA)/S(17+300/S))
hq hub height
hA Noise critical point height above terrain IP (= 5m)
DD : Vegetation damping figure (= 0)
DG : Build up damping figure (= 0)

瑞典

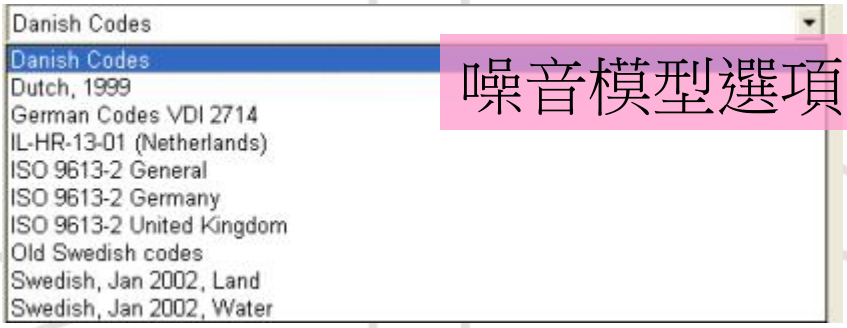
The old Swedish codes

The maximum noise impact from WTGs at a wind speed of 8 m/s is:

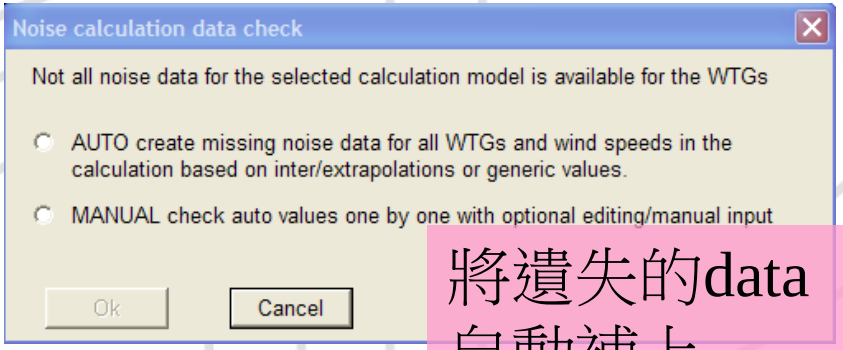
- Light industrial areas: 50 dB.
- Houses etc.: 40 dB.
- Recreational areas: 35 dB.

The damping coefficient α_a is set to 0.003 dB/m instead of 0.005 dB/m

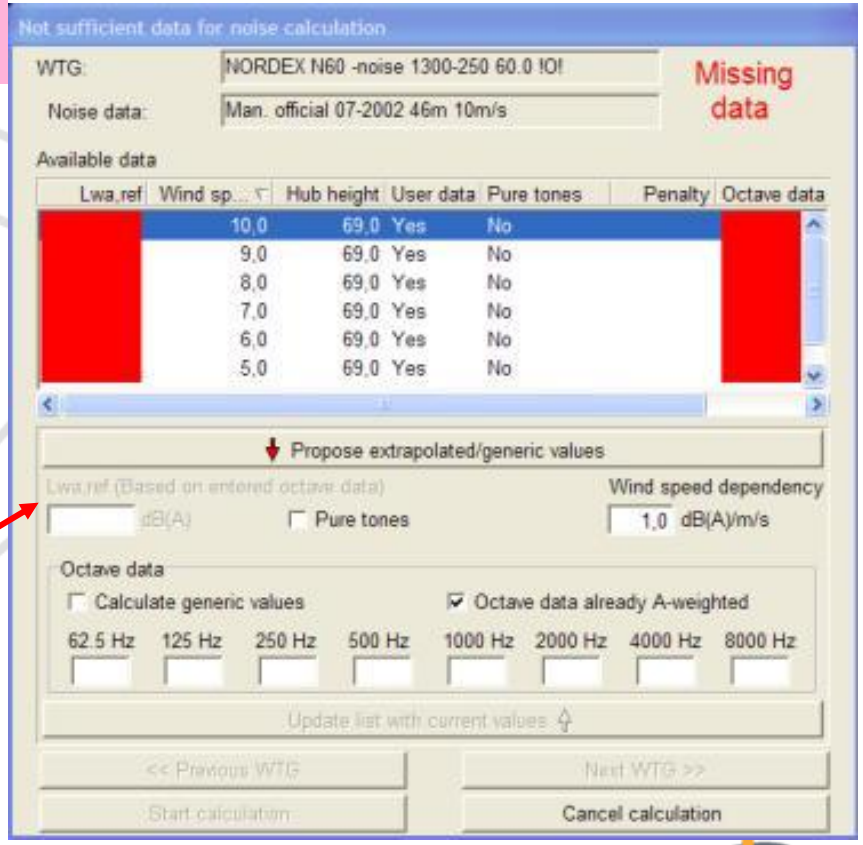
噪音模組

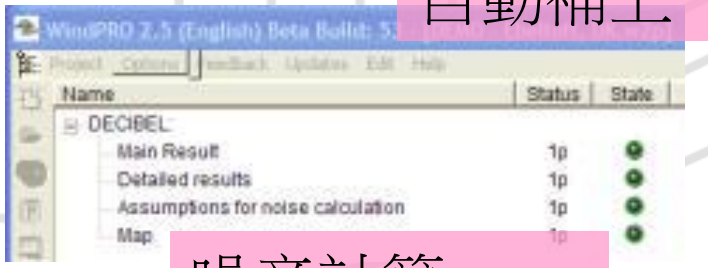


噪音模型選項



將遺失的data
自動補上

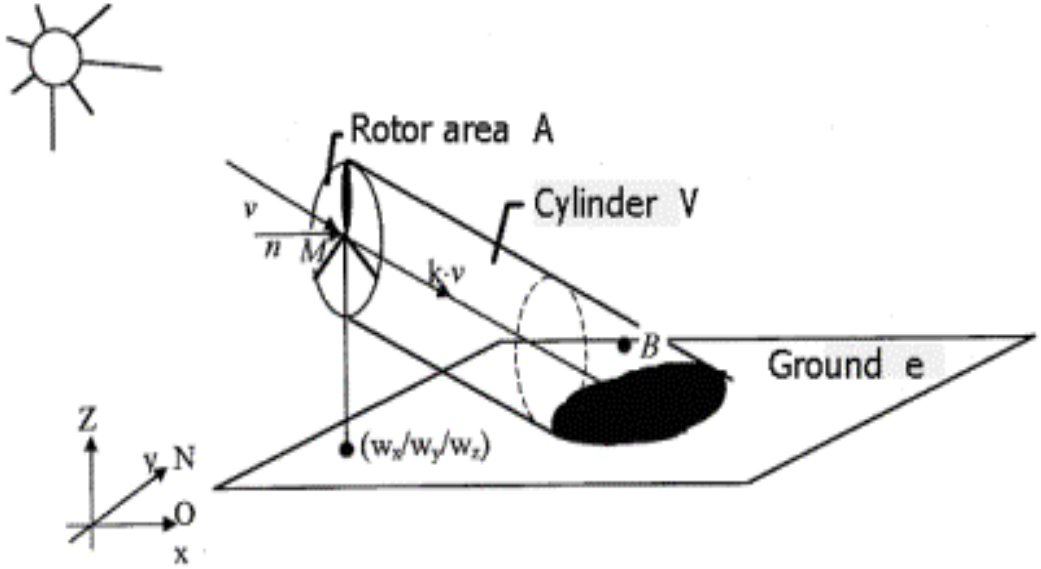


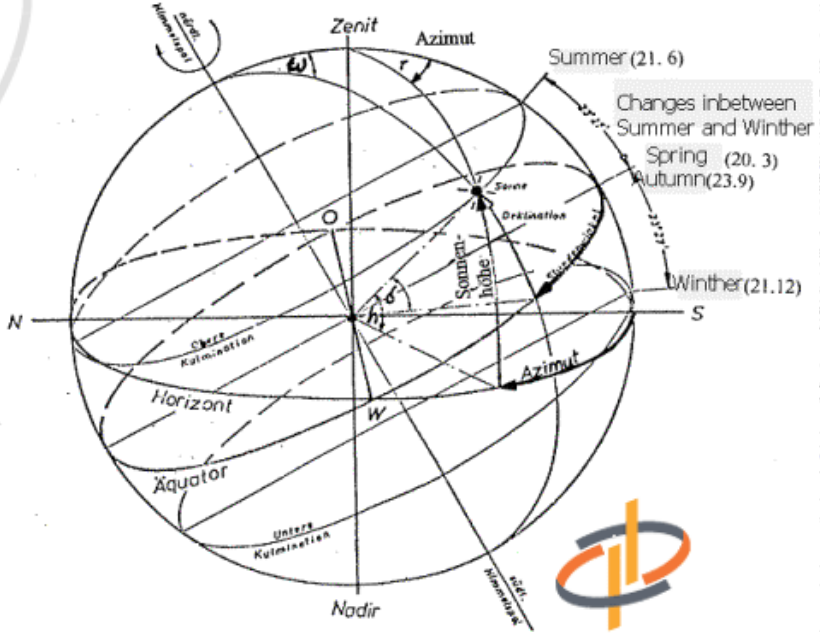


噪音計算

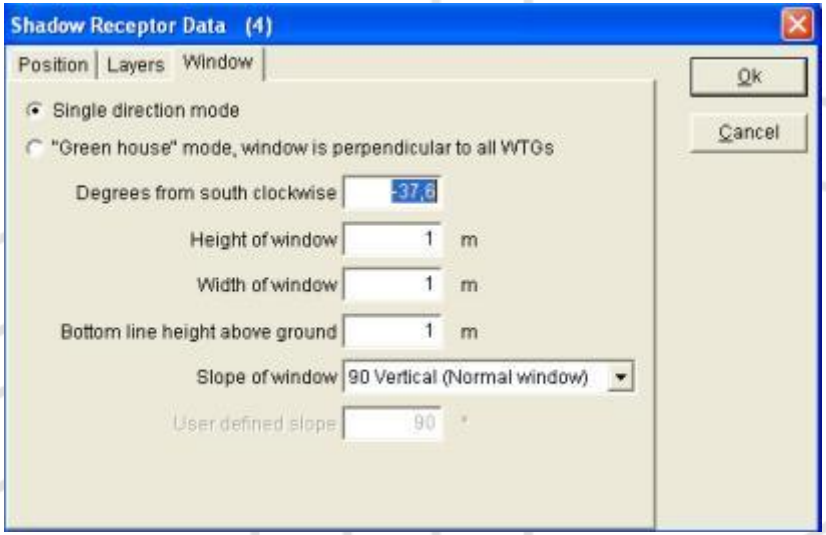
陰影模型

- 考慮風力發電機對附近建築物的影響
- 計算受體或給定區域發電機組閃爍效應 (flickering effect) 的年小時數，提供最壞情況和實際情況值
  - The diameter of the sun, D: 1,390,000 km
  - The distance to the sun, d: 150,000,000 km

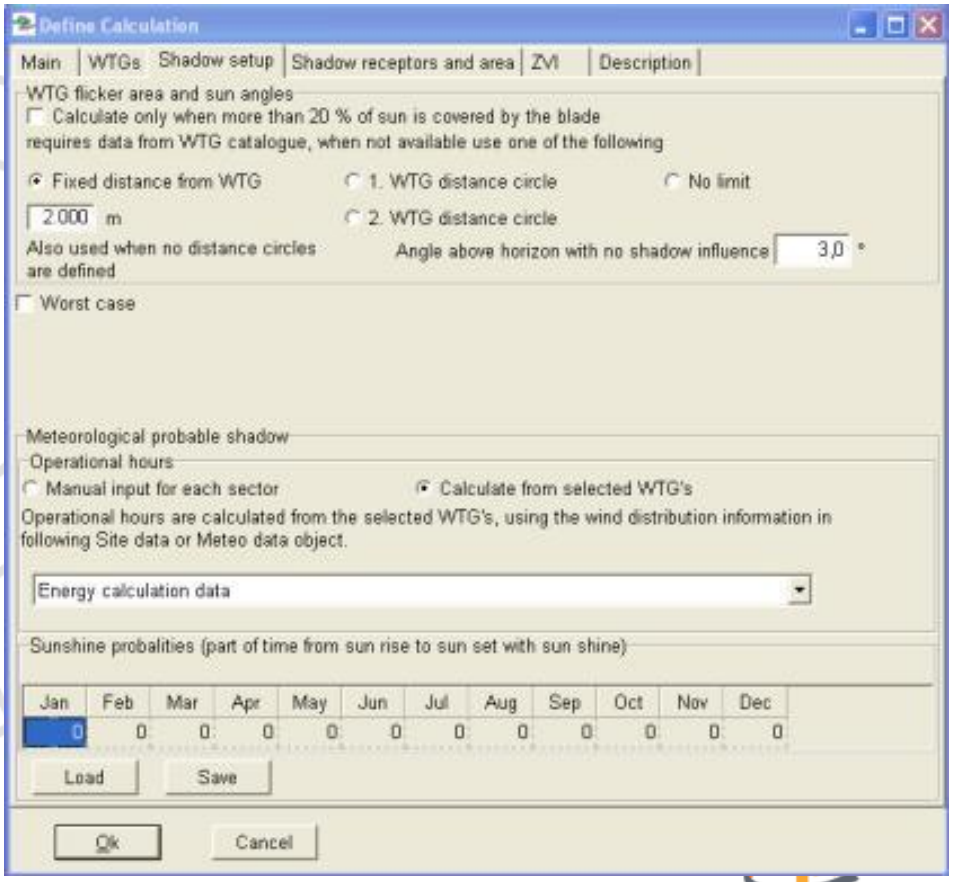




陰影模型

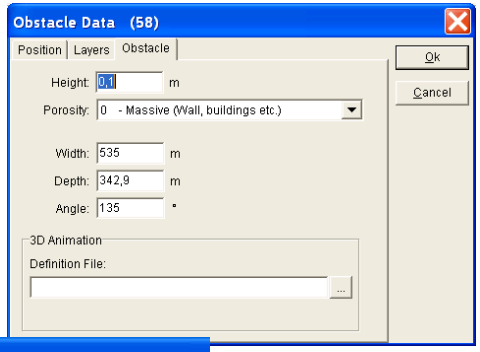

Shadow Receptor Data (4)
Position
Layers
Window
Ok
Cancel
Single direction mode
"Green house" mode, window is perpendicular to all WTGs
Degrees from south clockwise
37.6
Height of window
1
m
Width of window
1
m
Bottom line height above ground
1
m
Slope of window
90 Vertical (Normal window)
User defined slope
90

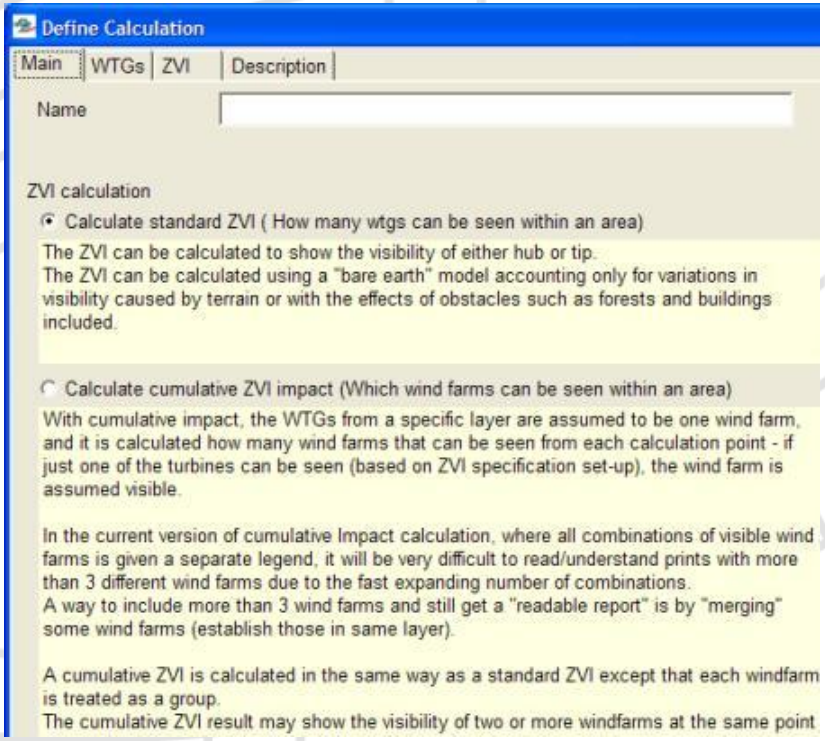

SHADOW Worst case with shadow map
Main Result 1p
Calendar 3p
Calendar, graphical 1p
Calendar per WTG
Calendar per WTG, graphical
Map 1p

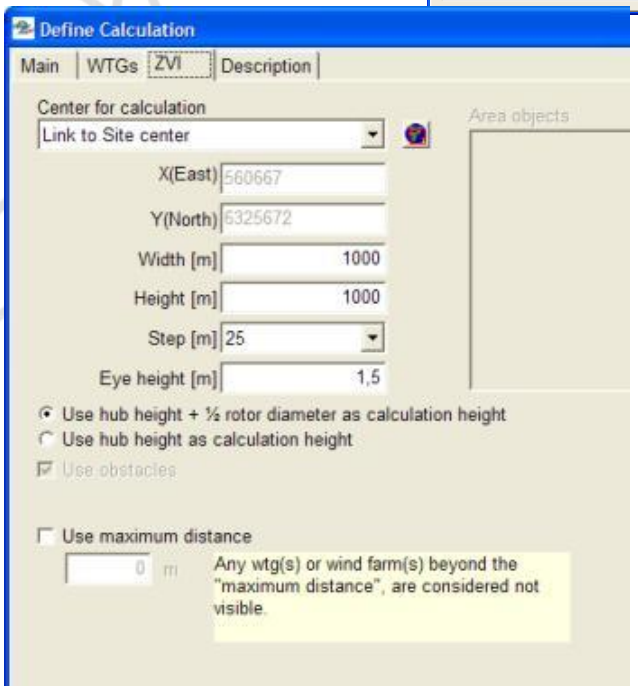

Define Calculation
Main
WTGs
Shadow setup
Shadow receptors and area
ZVI
Description
WTG flicker area and sun angles
Calculate only when more than 20 % of sun is covered by the blade
requires data from WTG catalogue, when not available use one of the following
Fixed distance from WTG
1. WTG distance circle
No limit
2000 m
2. WTG distance circle
Also used when no distance circles are defined
Angle above horizon with no shadow influence
3,0 °
Worst case
Meteorological probable shadow
Operational hours
Manual input for each sector
Calculate from selected WTG's
Operational hours are calculated from the selected WTG's, using the wind distribution information in following Site data or Meteo data object.
Energy calculation data
Sunshine probalities (part of time from sun rise to sun set with sun shine)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
0 0 0 0 0 0 0 0 0 0 0 0
Load
Save
Ok
Cancel

視覺影響區域模組 ZVI

- 能由等高線圖的高度模型來計算發電機組的視覺影響區域
- 需能設定線物件、面積物件和遮蔽物

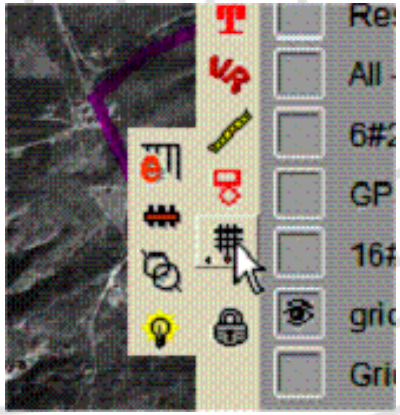


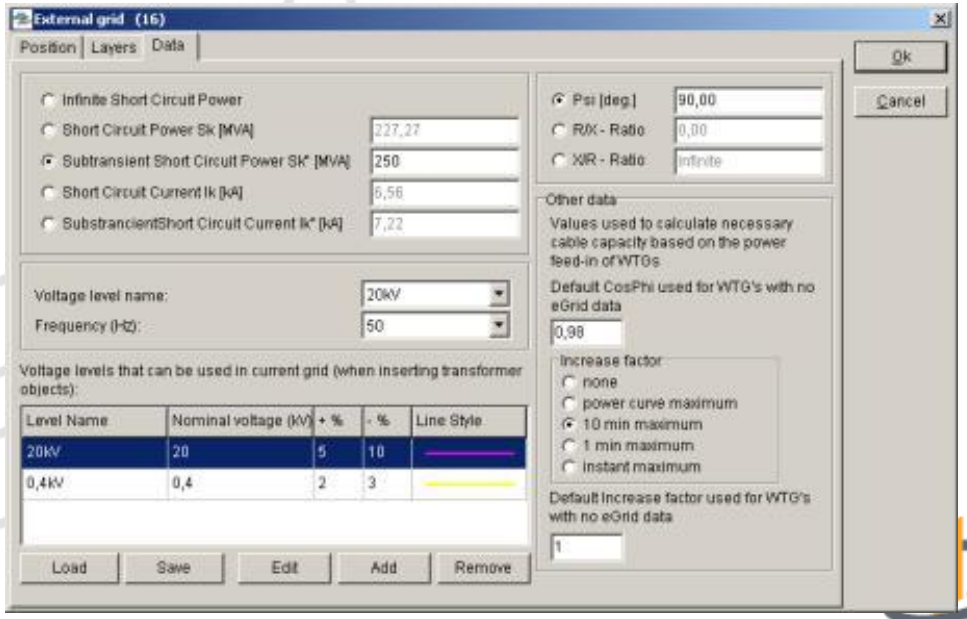




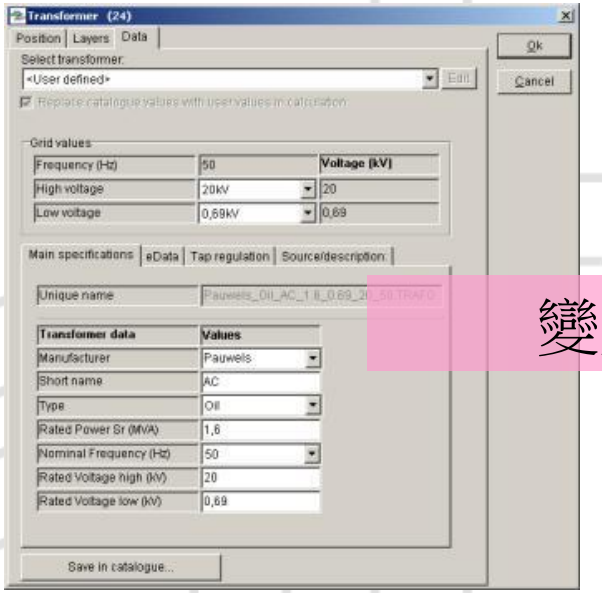
電網模組eGRID

- 需能計算基於當地風場對電纜與變壓器的年損耗
- 電纜與變壓器的容量百分比的負載
- 需能計算穩態電壓變化
- 短路電流、電壓閃變
- 開關效應的電壓變化
- 元件成本計算

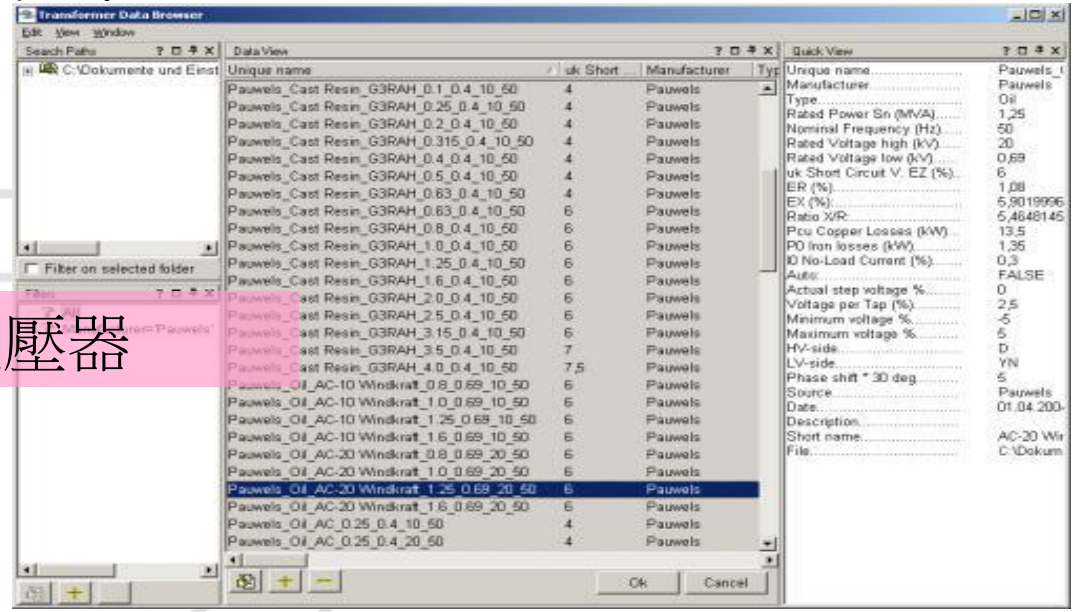




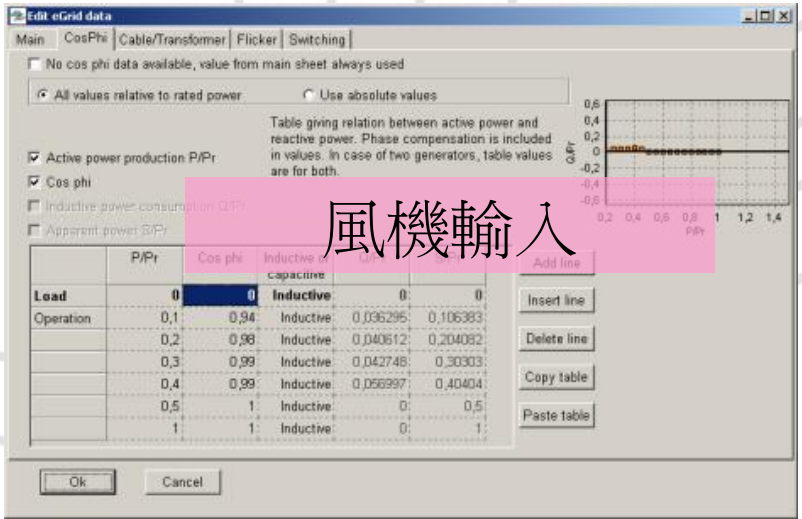
電網模組eGRID

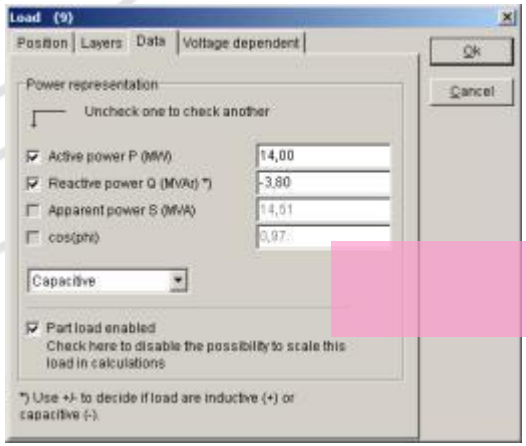


變壓器

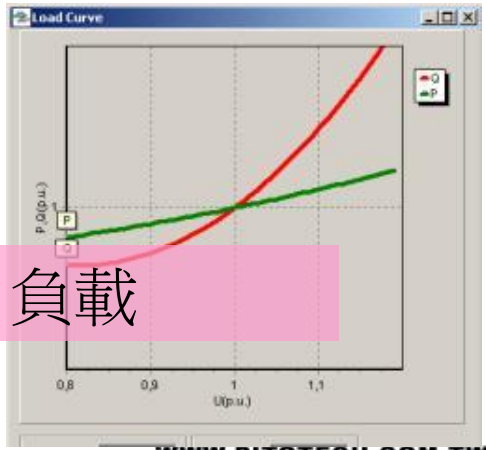


風機輸入

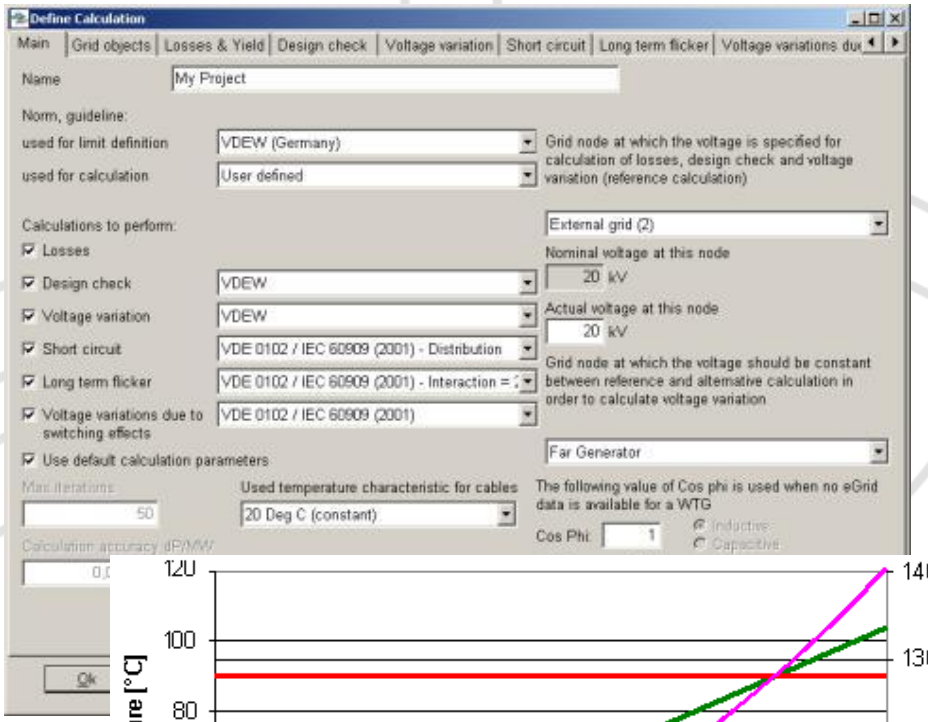


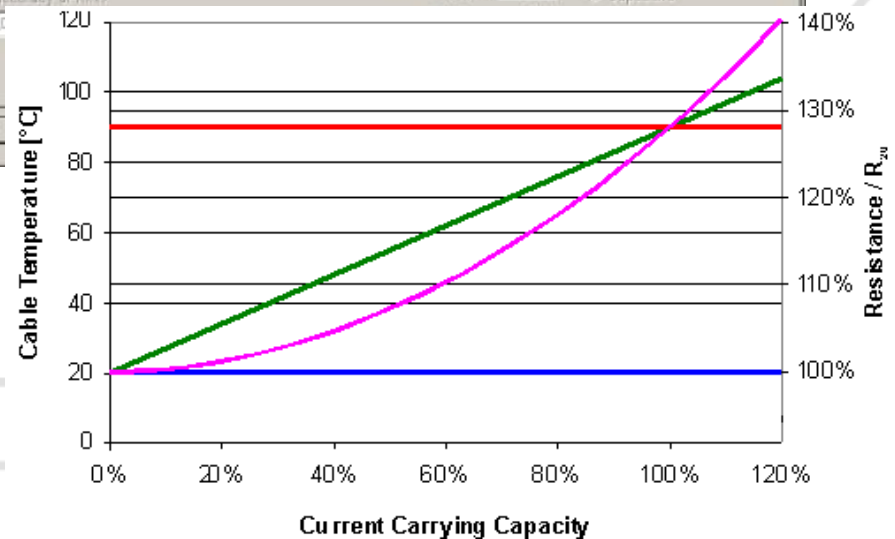


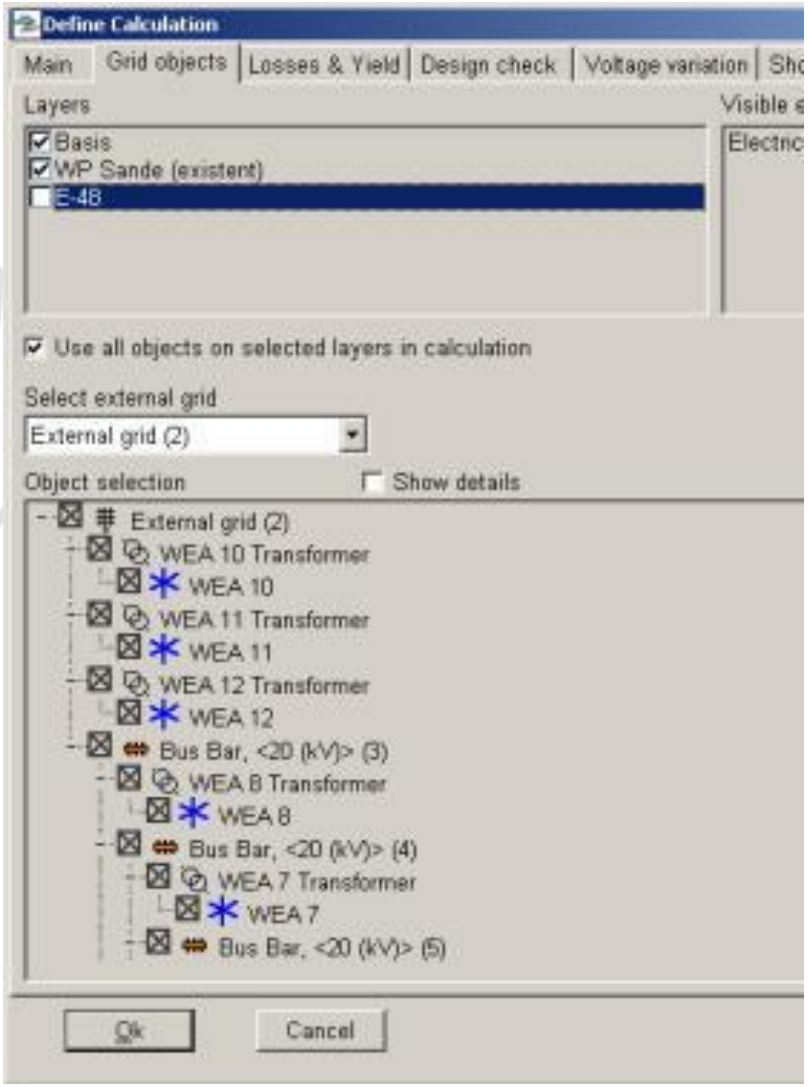
負載



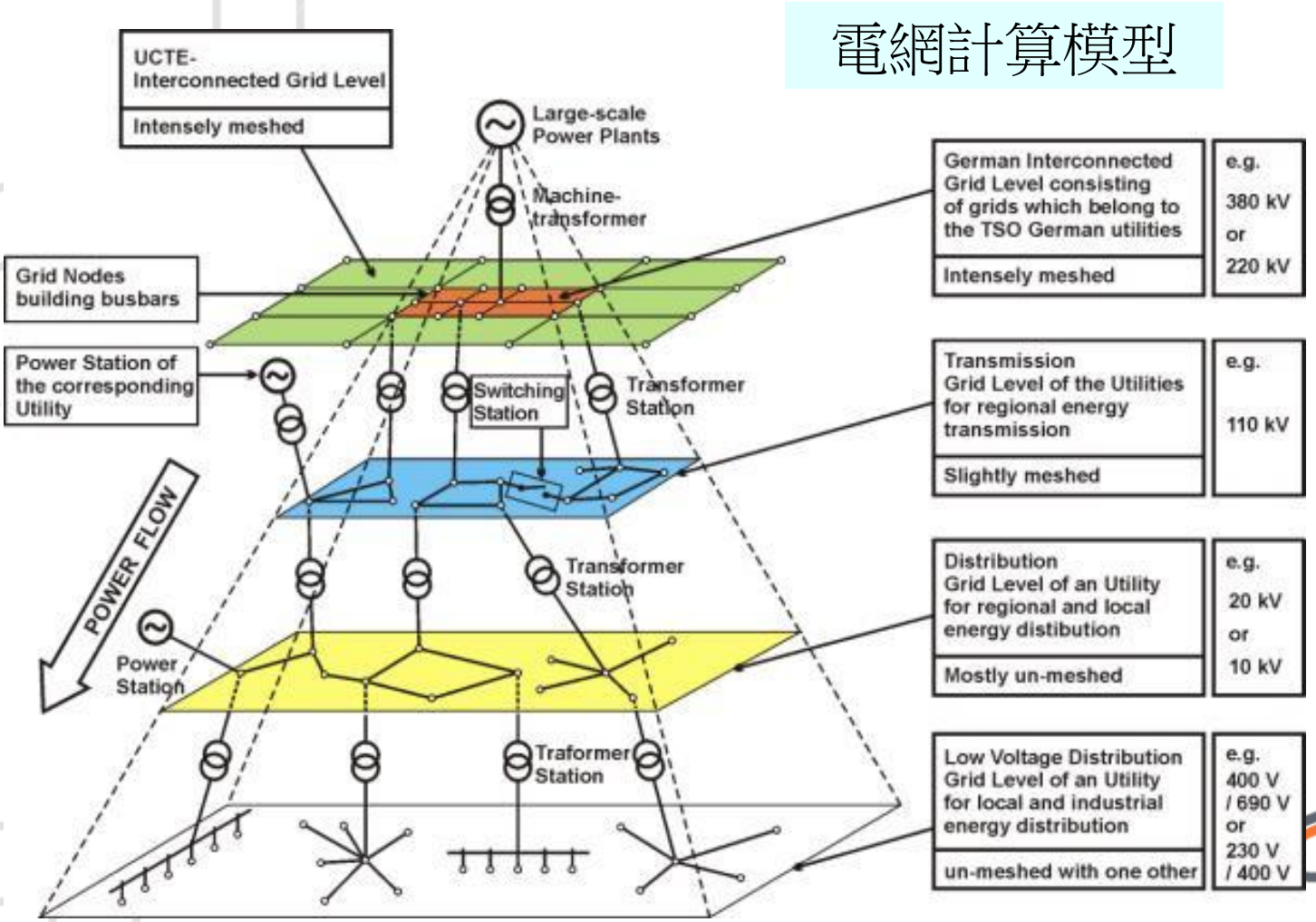
電網模組eGRID


Define Calculation
Main
Grid objects
Losses & Yield
Design check
Voltage variation
Short circuit
Long term flicker
Voltage variations du
Name
My Project
Norm, guideline:
used for limit definition
VDEW (Germany)
used for calculation
User defined
Grid node at which the voltage is specified for calculation of losses, design check and voltage variation (reference calculation)
Calculations to perform:
Losses
Design check
VDEW
Voltage variation
VDEW
Short circuit
VDE 0102 / IEC 60909 (2001) - Distribution
Long term flicker
VDE 0102 / IEC 60909 (2001) - Interaction =
Voltage variations due to switching effects
VDE 0102 / IEC 60909 (2001)
Use default calculation parameters
External grid (2)
Nominal voltage at this node
20 kV
Actual voltage at this node
20 kV
Grid node at which the voltage should be constant between reference and alternative calculation in order to calculate voltage variation
Far Generator
Used temperature characteristic for cables
20 Deg C (constant)
The following value of Cos phi is used when no eGrid data is available for a WTG
Cos Phi
1
Inductive
Capacitive
Ok


Cable Temperature [°C]
120
100
80
60
40
20
0
0%
20%
40%
60%
80%
100%
120%
Current Carrying Capacity
140%
130%
120%
110%
100%
Resistance / R20

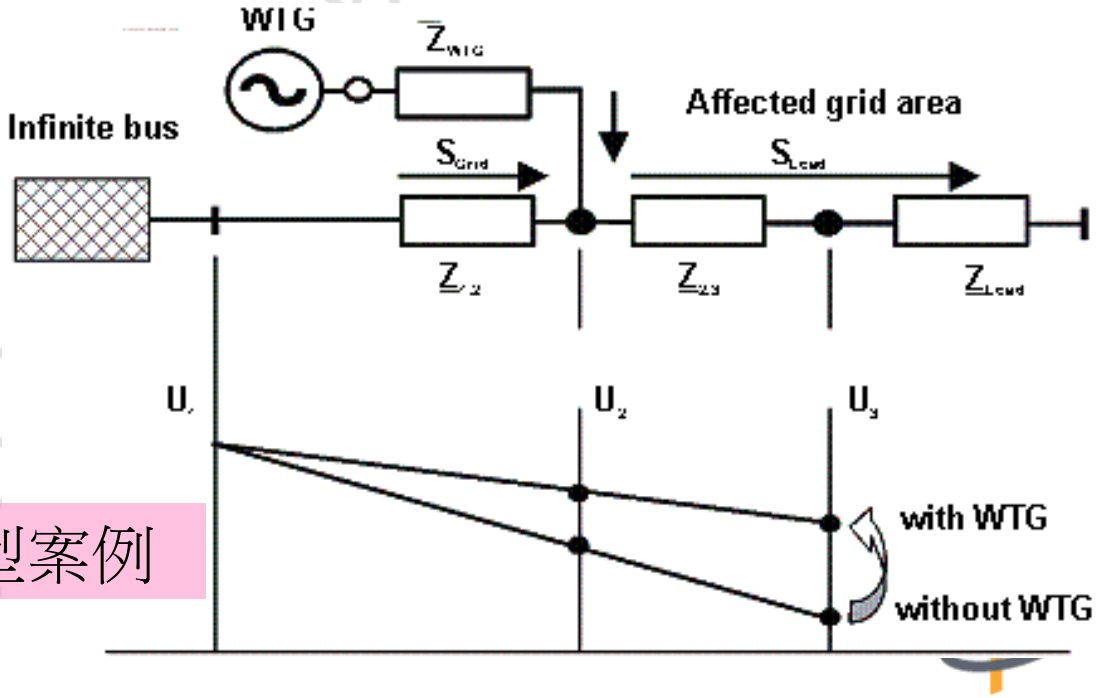

Define Calculation
Main
Grid objects
Losses & Yield
Design check
Voltage variation
Layers
Visible
Basis
WP Sande (existent)
E-48
Use all objects on selected layers in calculation
Select external grid
External grid (2)
Object selection
Show details
External grid (2)
WEA 10 Transformer
WEA 10
WEA 11 Transformer
WEA 11
WEA 12 Transformer
WEA 12
Bus Bar, <20 (kV)> (3)
WEA 8 Transformer
WEA 8
Bus Bar, <20 (kV)> (4)
WEA 7 Transformer
WEA 7
Bus Bar, <20 (kV)> (5)
Ok
Cancel

電網模組eGRID


電網計算模型
UCTE-
Interconnected Grid Level
Intensely meshed
Large-scale
Power Plants
Machine-
transformer
Grid Nodes
building busbars
Power Station of
the corresponding
Utility
Switching
Station
Transformer
Station
POWER FLOW
Transformer
Station
Power
Station
Traformer
Station
German Interconnected
Grid Level consisting
of grids which belong to
the TSO German utilities
Intensely meshed
e.g.
380 kV
or
220 kV
Transmission
Grid Level of the Utilities
for regional energy
transmission
Slightly meshed
e.g.
110 kV
Distribution
Grid Level of an Utility
for regional and local
energy distibution
Mostly un-meshed
e.g.
20 kV
or
10 kV
Low Voltage Distribution
Grid Level of an Utility
for local and industrial
energy distribution
un-meshed with one other
e.g.
400 V
/ 690 V
or
230 V
/ 400 V

電網模組eGRID

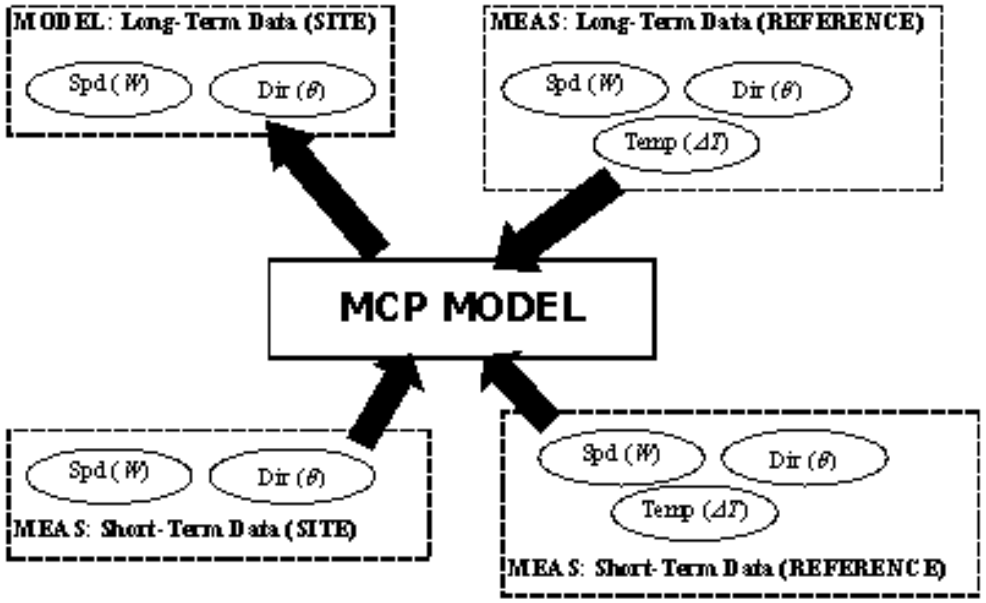
- Voltage variations also by flickers
- Variations of the short-circuit current
- Power factors
- Harmonics



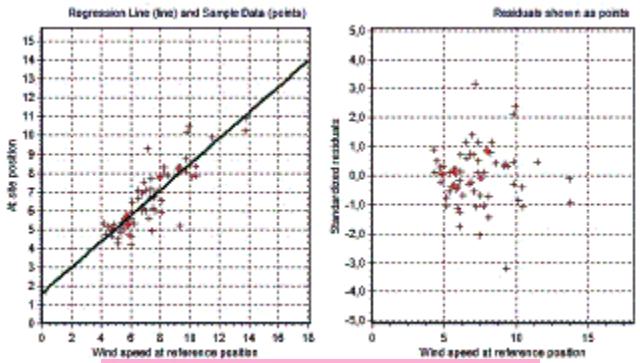
風機與市電整合的典型案例

量測修正預測模組MCP

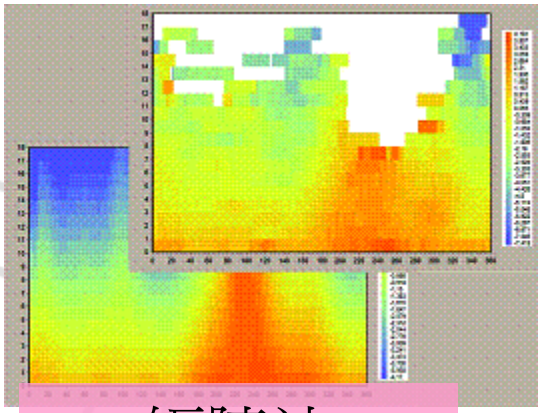
- 具備四種方法：線性回歸法、矩陣法、韋伯尺度法和風力指標法進行數據的修正與預測
- 需能產生總覽報告和四種方法的細部報告



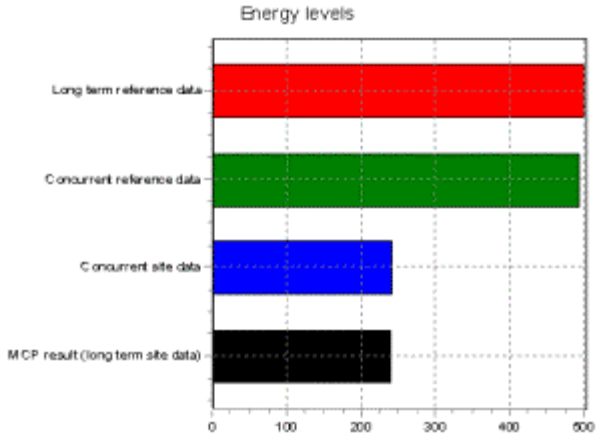
量測修正預測模組MCP



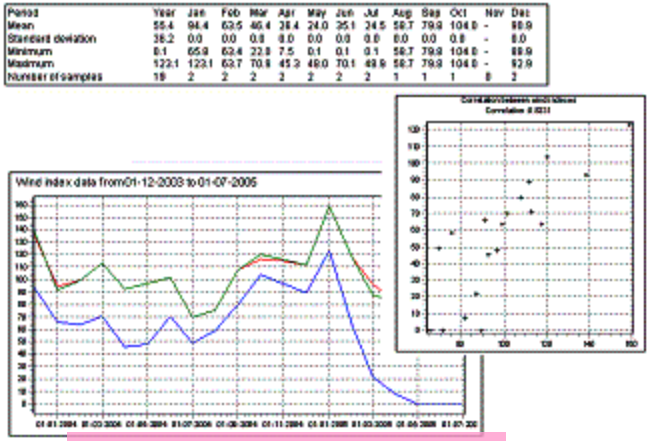
線性回歸法



矩陣法

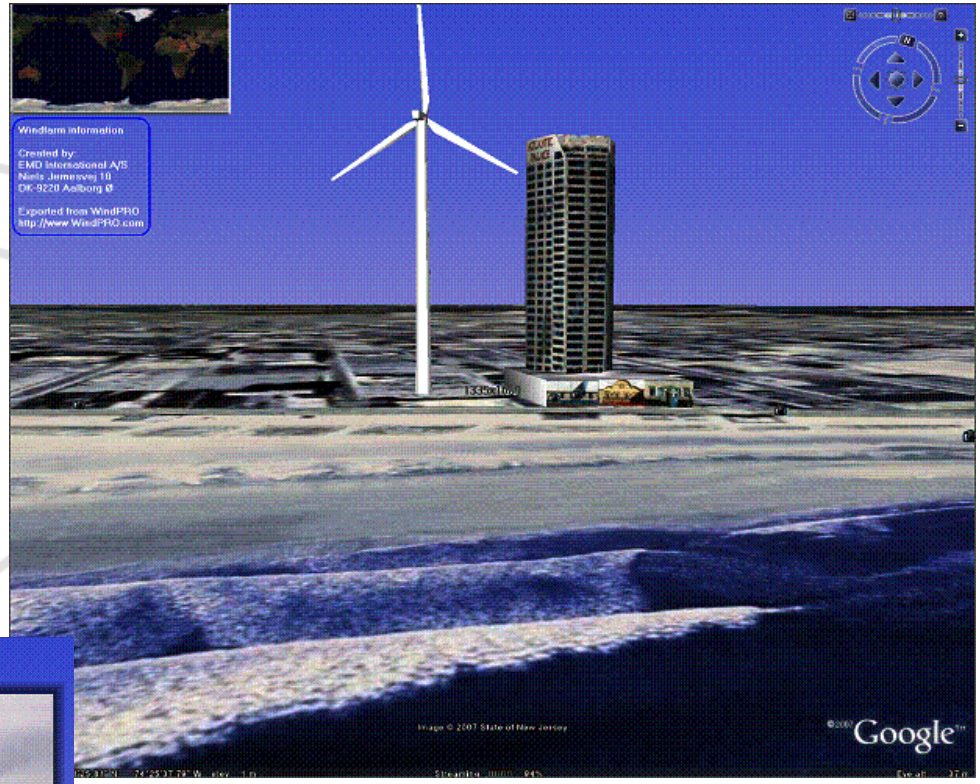


韋伯尺度法



風力指標法

Google Earth Export



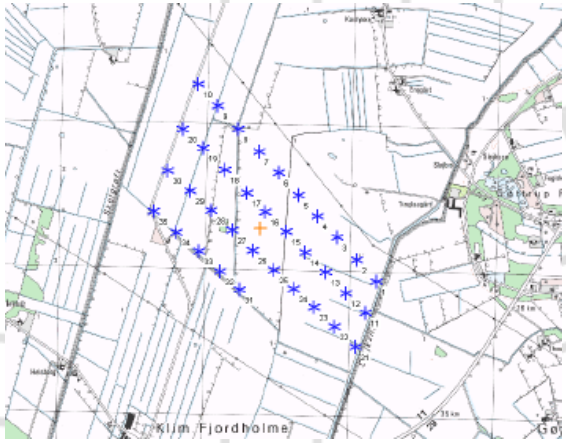
相片合成

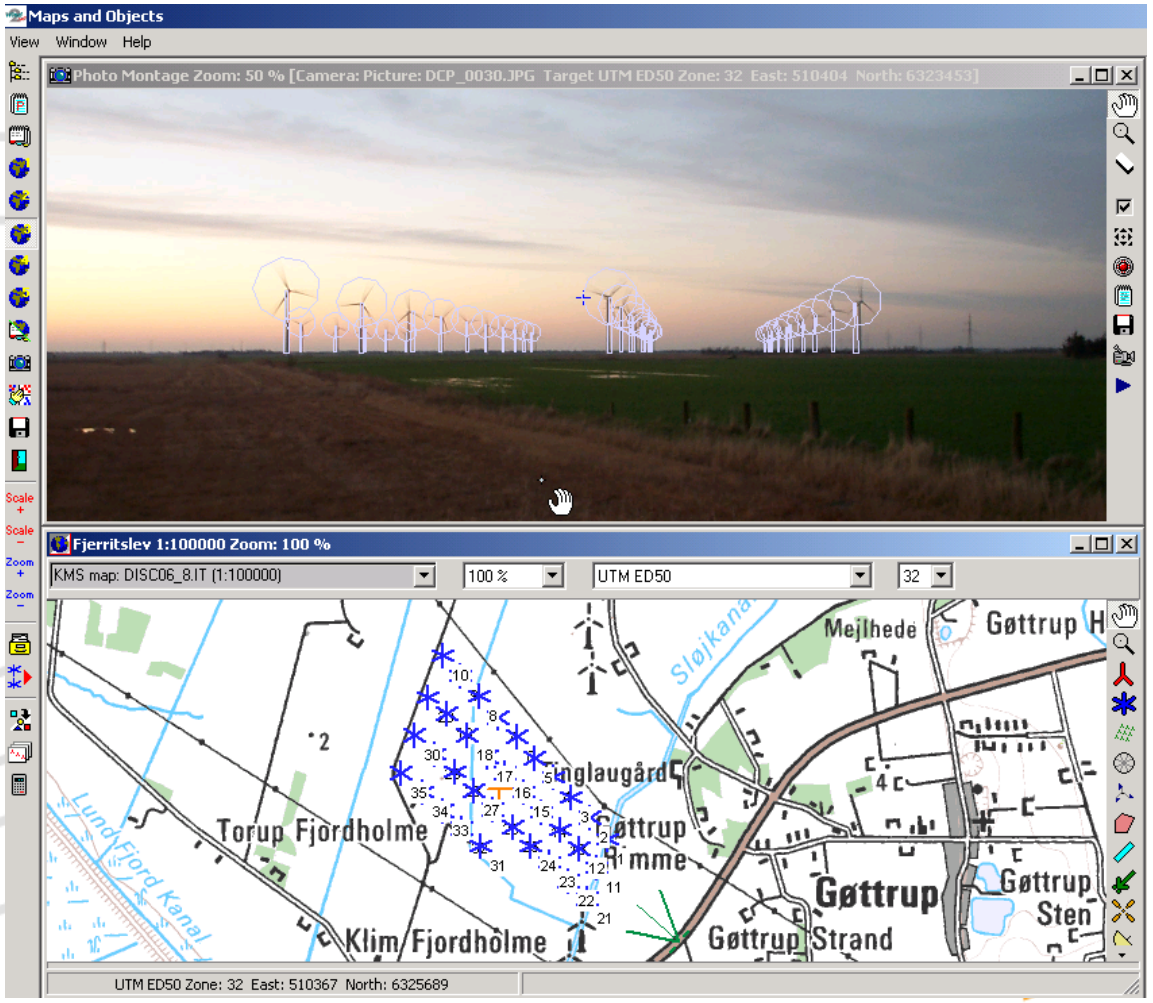
Case study: Klim, Denmark

- 地形特點: 平坦、開放、內陸、靠近峽灣
- 專案內容:
  - 風機地點在丹麥西北部約東經9º09‘北緯57º04’, 位於Fjerritslev的西南方7公里, 稱為Klim Fjordholme
  - 平均風速7m/s @ 44 m a.g.l (Hub高度)
  - 風電廠中包含35台WTG, 所有皆為Vestas V44, 600KW, with typical spacing: 4.5 RD in rows and 5.5 – 7 between rows.
  - 第一年僅建置13台WTG, 第二年才擴充到35台

- Main Issue:
  - 確認PARK計算模型(Wake-loss)
  - 未量測此處的風資料, 使用約35公里遠的Silstrup的風資料
  - 僅量測此處約10分鐘的發電量
- Main Result:
  - 完整風電廠的真實發電量計算必須非常精確, 主要與PARK的計算方法有關
  - 測試地形平坦,主要使用Wake decay constant 0.075(open land),對迎風的前兩排風機很有效益,
  - 0.04則代表off shore, 對後面幾排的風機較適用

Case study: Klim, Denmark





Case study: Klim, Denmark

- 根據下表, 長期計算平均發電量約為49 GWh/year (1400 MWh/WTG/year)
- 1998-2000的平均發電量為45.4 GWh

21000A KLIM

35 stk. VESTAS 600 kW Navhøjde 45.0 m

Anlægsdata			
Rotordiameter/rotorareal/Spec. effekt	44.0 m	1520.5 m2	0.39 kW/m2
Amt/Kommune (kommunenr.)	Nordjylland	Fjerritslev(811)	
UTM-koordinater (Zone/Øst/Nord)	32	509807	6323586
UTM præcision	Rimeligpræcis (±100m)		
Beregnet årsproduktion (MWh pr. år/Ber. af)	46000.0	FAB	
Indkøring/data start/data slut	Sep 1997	Jan 1998	Sep 2001

HOVEDRESULTATER	NE-index	DMI-index
Vindkorrigeret årsproduktion (MWh)	50280.4	48579.7
VKP/rotorareal (kWh/m2)	944.8	912.8
VKP pr. kW generatoreffekt (kWh/kW)	2394.3	2313.3
GODHED	1.09	1.06

Baseretpåperioden Jan 1998- Sep2001

Månedligeproduktioner og GODHEDER (GODHED baseret på: NE-index).

År	Data	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec	SUM	Pr. år
1998	kWh	4,414,500	6,724,300	*	2,982,900	2,548,700	3,729,000	4,144,300	*	2,769,100	6,208,200	2,558,000	4,811,500	40,890,500	44,249,700
	Godhed	1.14	0.99		1.04	0.96	1.20	1.09		1.03	0.96	1.11	1.17	1.06	0.95
1999	kWh	5,340,700	*	4,010,160	3,687,100	3,536,400	2,346,600	1,899,800	1,362,900	2,399,400	4,312,500	4,506,170	6,176,260	39,577,992	43,289,928
	Godhed	1.18		1.23	0.94	1.26	1.18	1.10	0.83	1.01	1.06	1.20	1.13	1.11	1.10
2000	kWh	6,824,920	6,289,540	4,996,180	*	2,774,680	*	2,372,630	3,341,000	3,644,370	4,108,900	4,674,360	3,675,070	42,701,648	48,729,980
	Godhed	1.14	1.01	1.03		1.13		1.13	1.34	1.05	1.09	1.18	1.18	1.11	1.11
2001	kWh	2,998,190	4,881,170	2,845,665	2,695,450	3,202,020	3,263,150	2,360,350	3,101,390	2,020,730				27,168,114	19,134,372
	Godhed	1.10	1.11	0.88	1.02	1.16	1.29	1.34	1.17	0.79				1.08	0.77
Sum	kWh	19,578,310	17,895,010	11,852,005	9,365,450	12,061,800	9,338,750	10,777,080	7,805,290	10,833,600	14,629,600	11,738,530	14,662,830	150,338,256	155,403,984
Middel	kWh	4,894,578	5,898,337	3,950,668	3,121,817	3,015,450	3,112,917	2,694,270	2,601,763	2,708,400	4,876,534	3,912,843	4,887,610		
	Godhed	1.14	1.04	1.05	1.00	1.13	1.22	1.16	1.11	0.97	1.04	1.17	1.16		

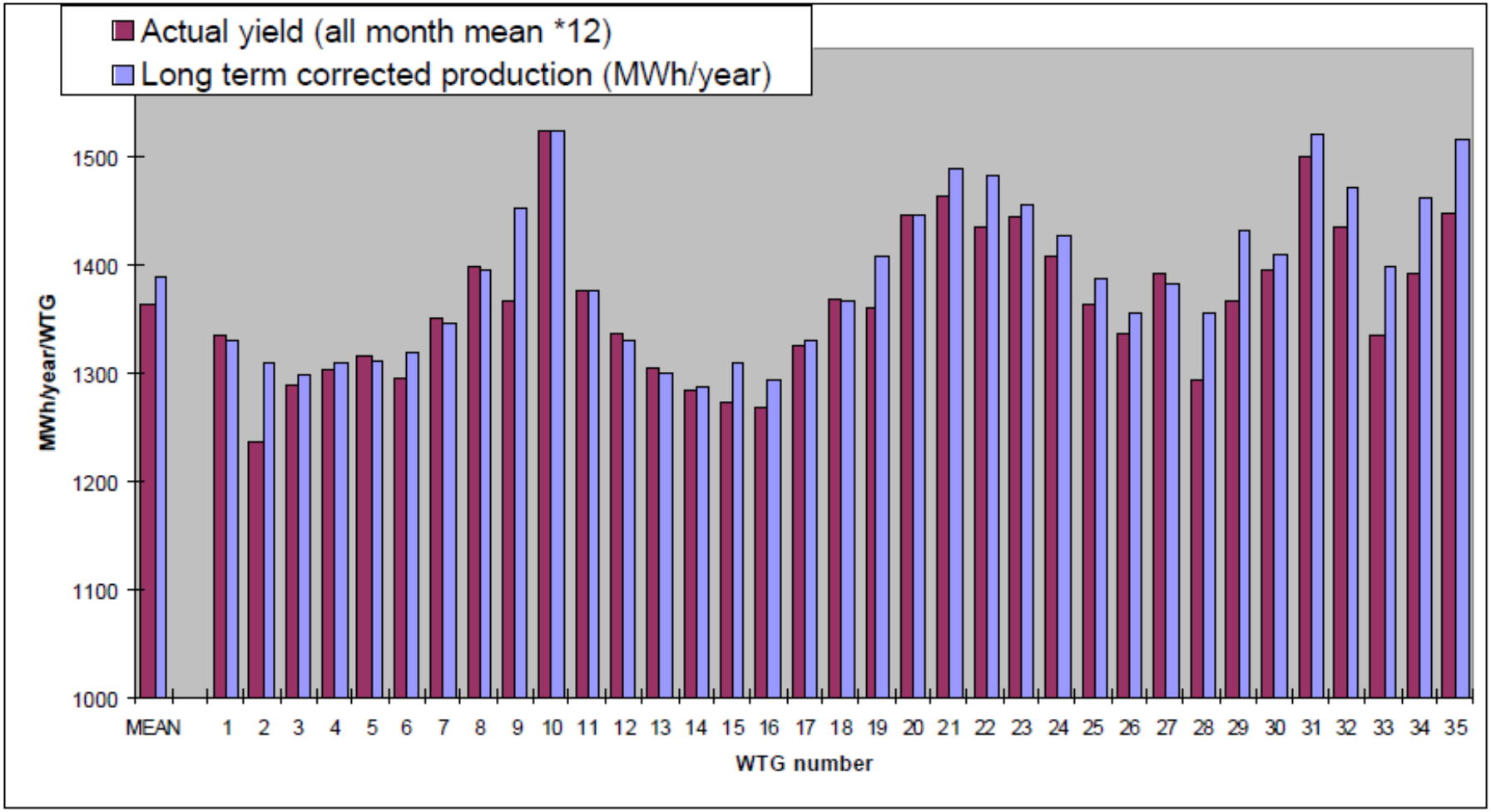
NOTE: Pr. årerrapporteretårsproduktion. *: Produktionstalikkeangivet.

År	1998	1999	2000	2001	Gns.
Produktion (MWh)	44,250	43,290	48,730	19,134	45,423
VKP (NE) MWh	43,920	50,386	51,071	35,271	48,459
VKP (DMI) MWh	45,424	49,756	51,765	24,696	48,982

Gns.erbaseretpå3hele år: 1998-2000

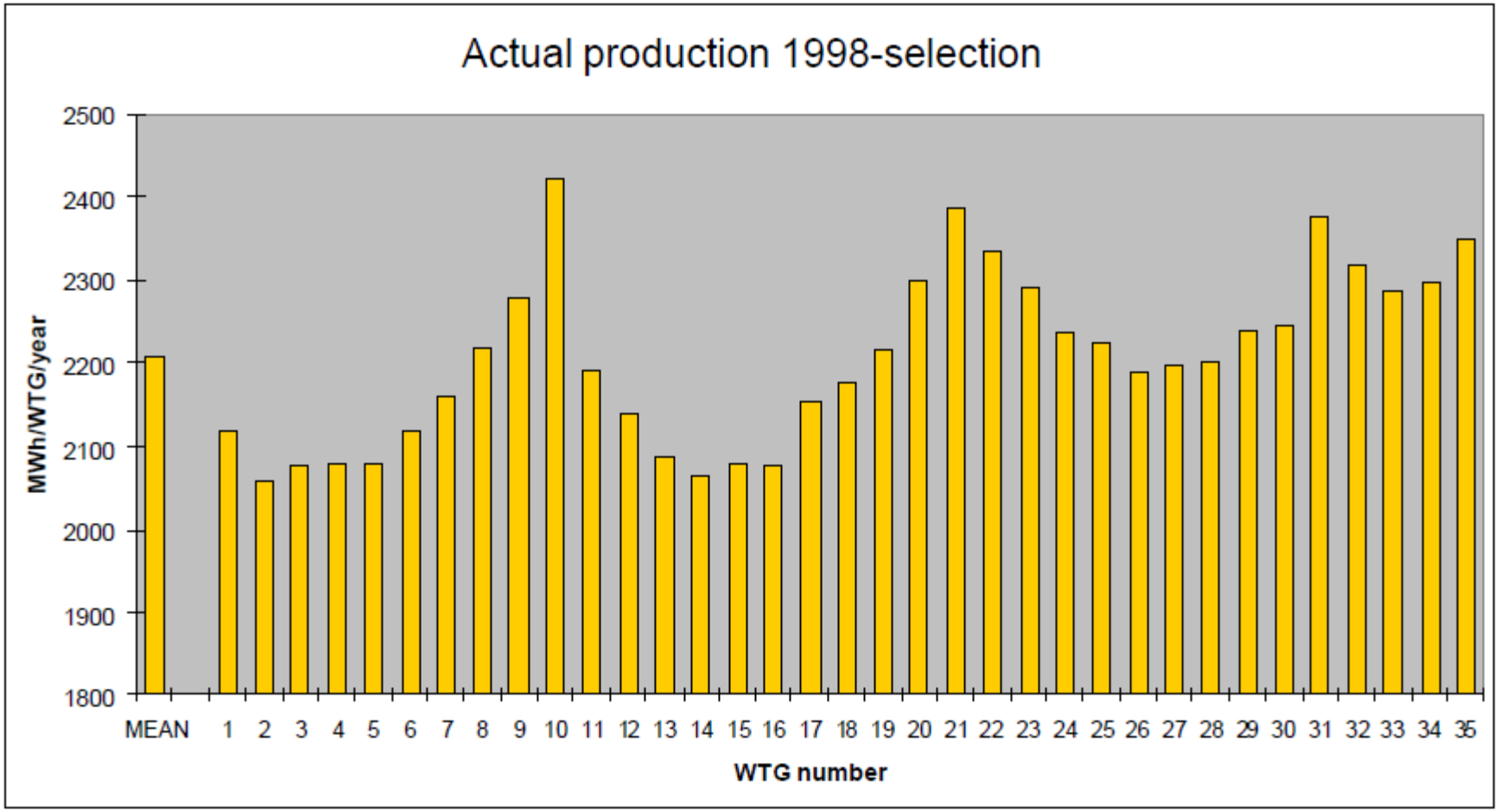
* Data for the whole wind farm from the VINDSTAT database.

Case study: Klim, Denmark



Actual and long term corrected energy production for each WTG

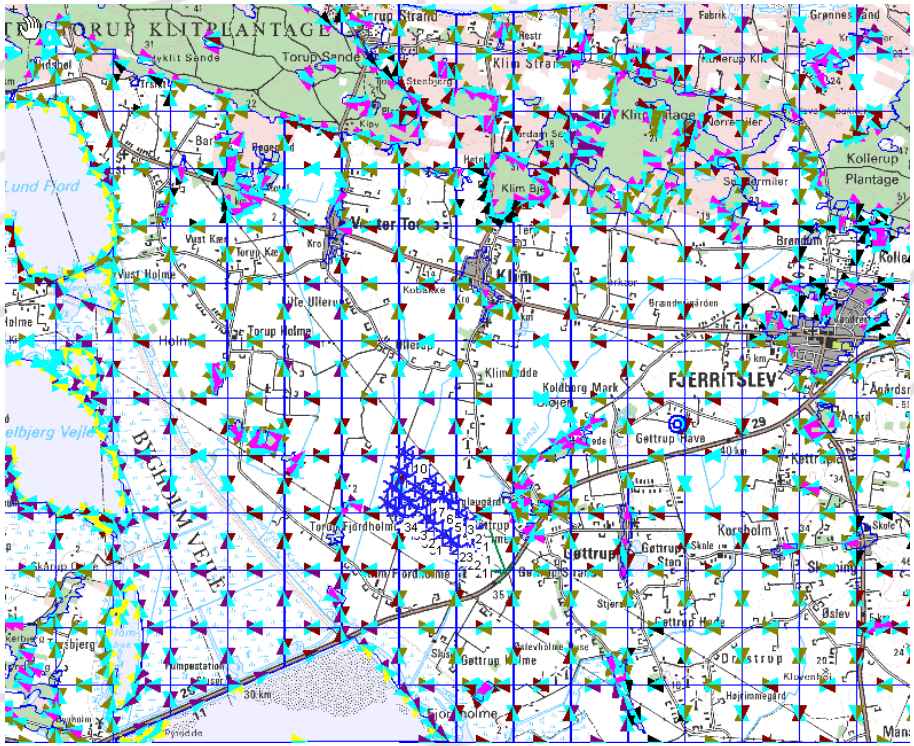
Case study: Klim, Denmark



Production for each WTG for the selected days with 100% availability used in parallel with Silstrup measure data for same days

Case study: Klim, Denmark

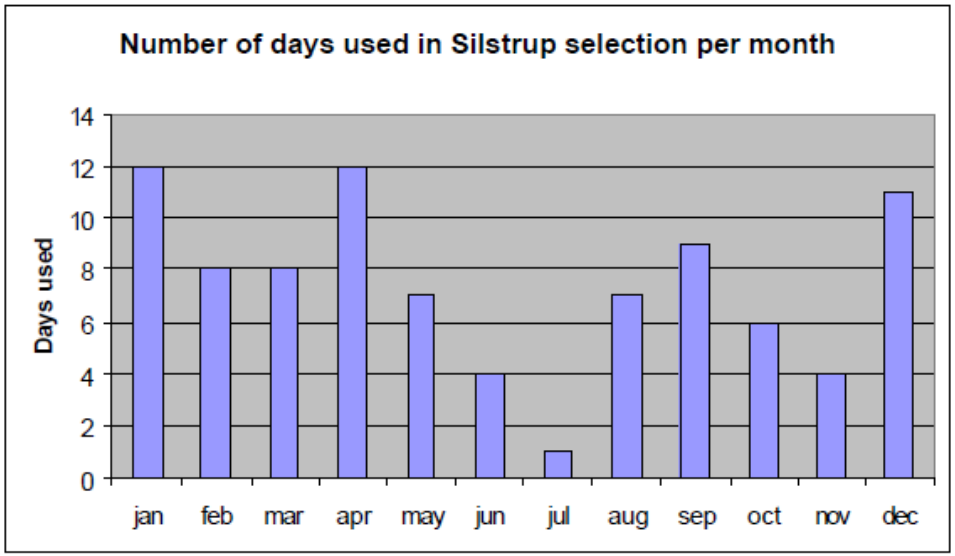
- Energy Calculation Assumptions ─ 計算模型與資料
  - Calculation model: PARK model ─ N.O. Jensen (Wake Model)



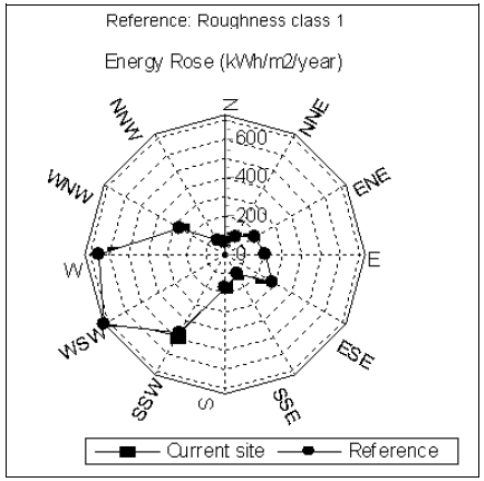
- 地形估計
  - 從南邊的峽灣到北邊都是森林, 考慮防風林對風力分布的影響, 重新數據化, 每平方公里都包含風力的粗估值。
  - 此區域地形相當平坦,包含森林、城市與河水區域。
  - 尚未考慮Height contour line與當地障礙物

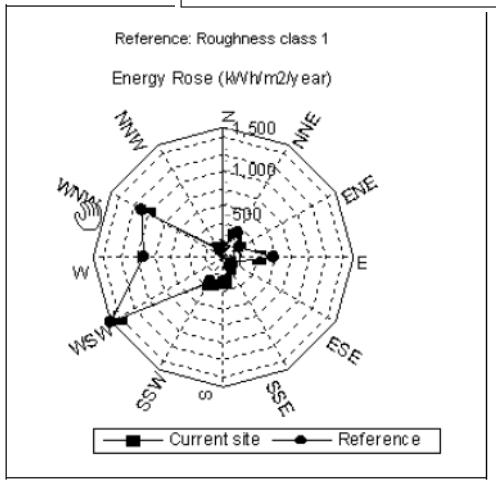
Case study: Klim, Denmark

- 風資料:
  - 一般的風資料Denmark 92: 方塊顯示針對Klim調整過
  - 本地的風資料-取自Silstrup



As well summer as winter months is included fairly equal in the 1998 Silstrup selection





Silstrup 1998-selection (89 days) energy rose.

Case study: Klim, Denmark

- WTG資料

Power curve: Manufactor 24/8-2000 1.225 20.00 0.00
Source Manufactor 24/8-2000

Source date	Creator	Created	Edited	Default	Stop windSpeed [m/s]	Air density [kg/m3]	Tip angle [°]	Power control	CT curve type
30-12-1899 00:00	EMD	20-11-2000 14:02	20-11-2000 14:03	No	20.0	1.225	0.0	Pitch	User defined

Power curve

Wind speed [m/s]	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
Power [kW]	0.00	0.00	30.00	77.00	135.00	206.00	287.00	371.00	450.00	514.00	555.00	562.00	584.00	595.00	600.00	600.00	600.00	600.00
Ce	0.000	0.000	0.256	0.360	0.423	0.432	0.423	0.396	0.363	0.319	0.273	0.226	0.169	0.157	0.131	0.110	0.094	0.081

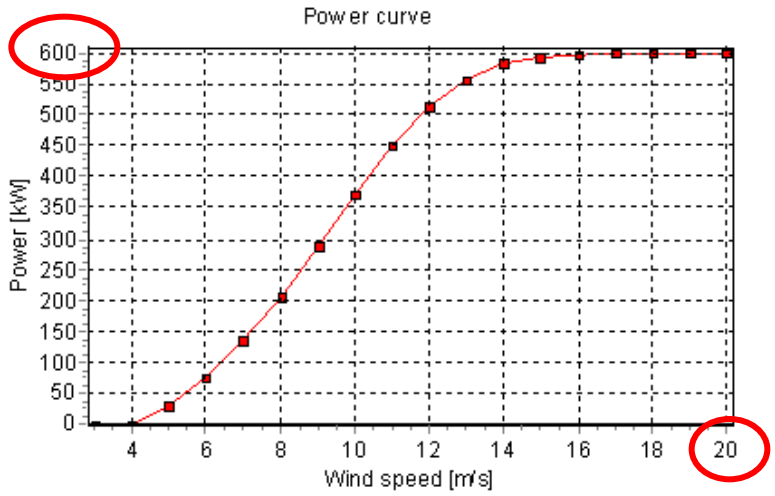
Ct curve

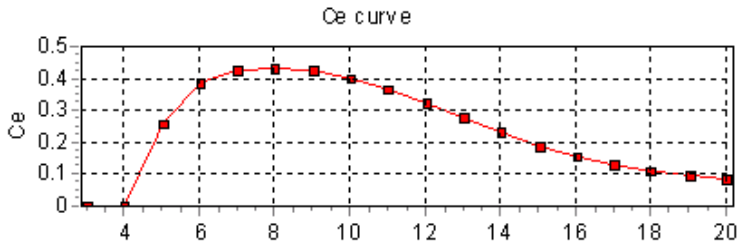
Wind speed [m/s]	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	18.00
Ct	0.00	0.00	0.85	0.83	0.79	0.73	0.67	0.60	0.54	0.48	0.40	0.32	0.25	0.20	0.14

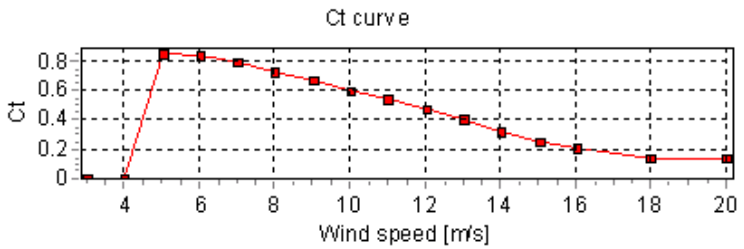
HP curve comparision

Vmean	[m/s]	5	6	7	8	9	10
HP value	[MWh]	752	1,211	1,670	2,099	2,489	2,835
Manufactor 24/8-2000 1.225 20.00 0.00	[MWh]	686	1,124	1,572	1,977	2,301	2,529

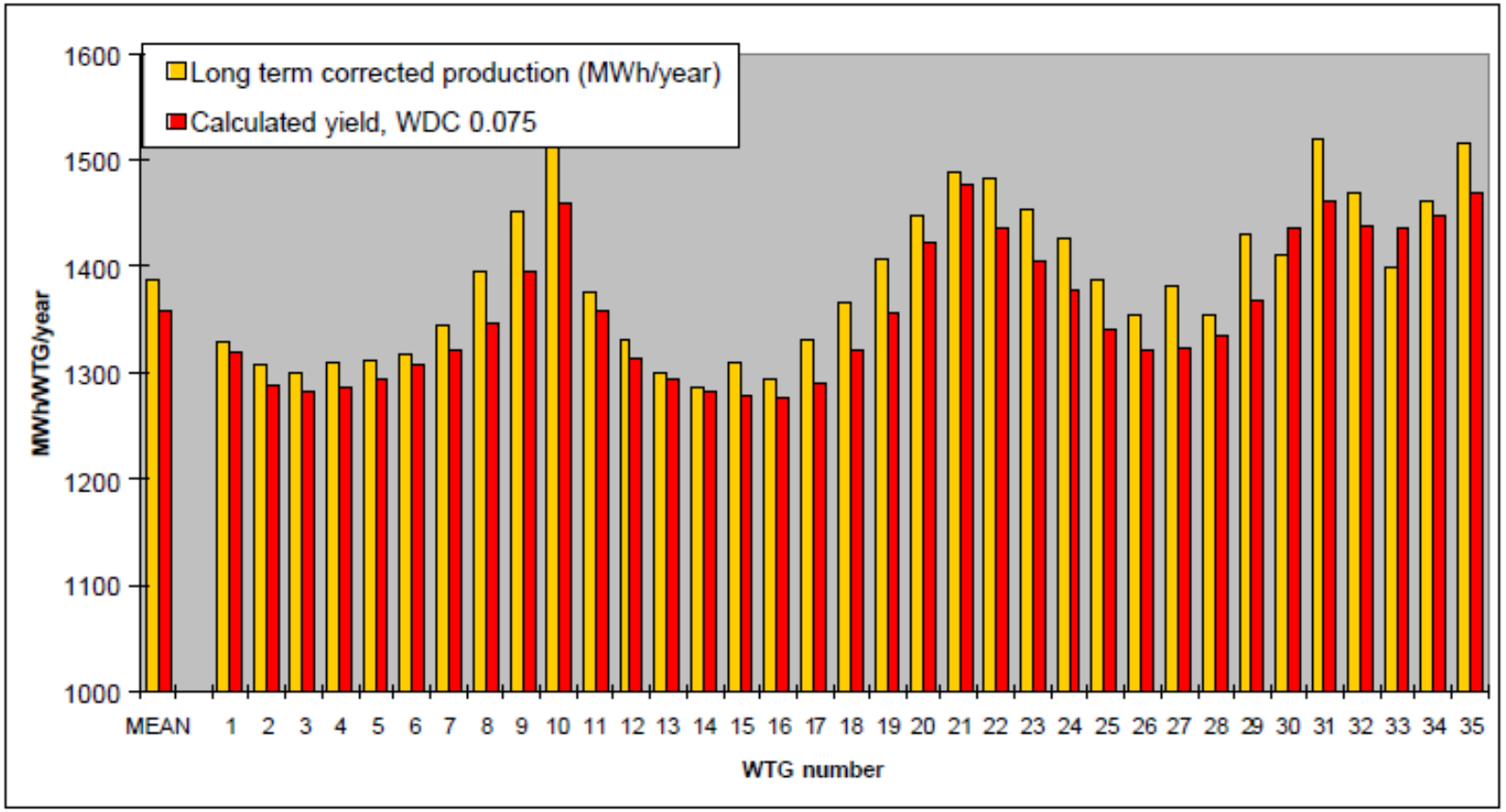
The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (W/m^2) and single/dual speed or stall/pitch decides the calculated values. For further details, ask at the Danish Energy Agency for project report J.no. 51171/00-0016, or use WindPRO







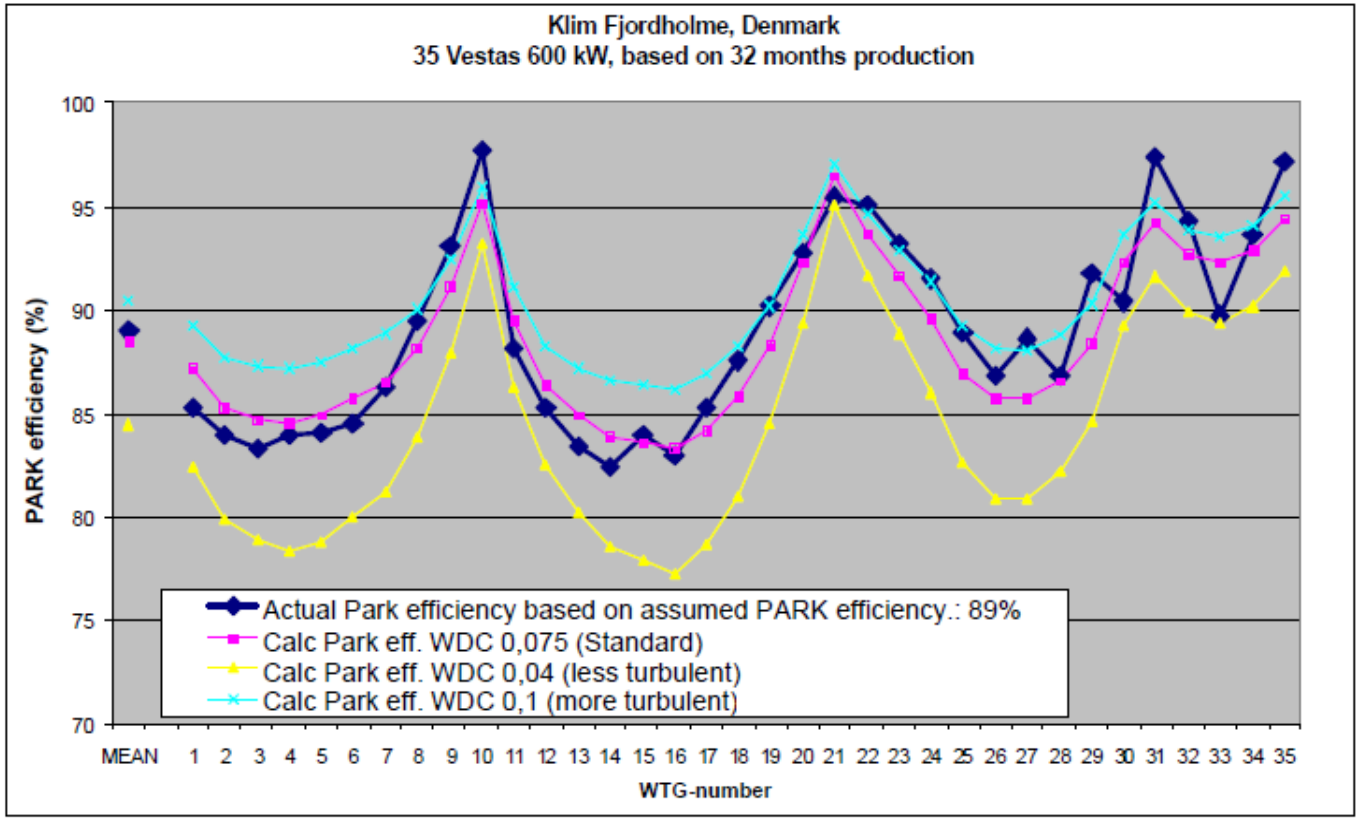
Case study: Klim, Denmark



The "first shot" calculation simply hit the actual value. Calculation is 2 % lower than actual, before power curve correction. Power curve corrected with 2% add on to calculation, there will be exact match. So for the result as a whole the match cannot be expected better. Also the variations within the WTGs seem fairly well.

Case study: Klim, Denmark

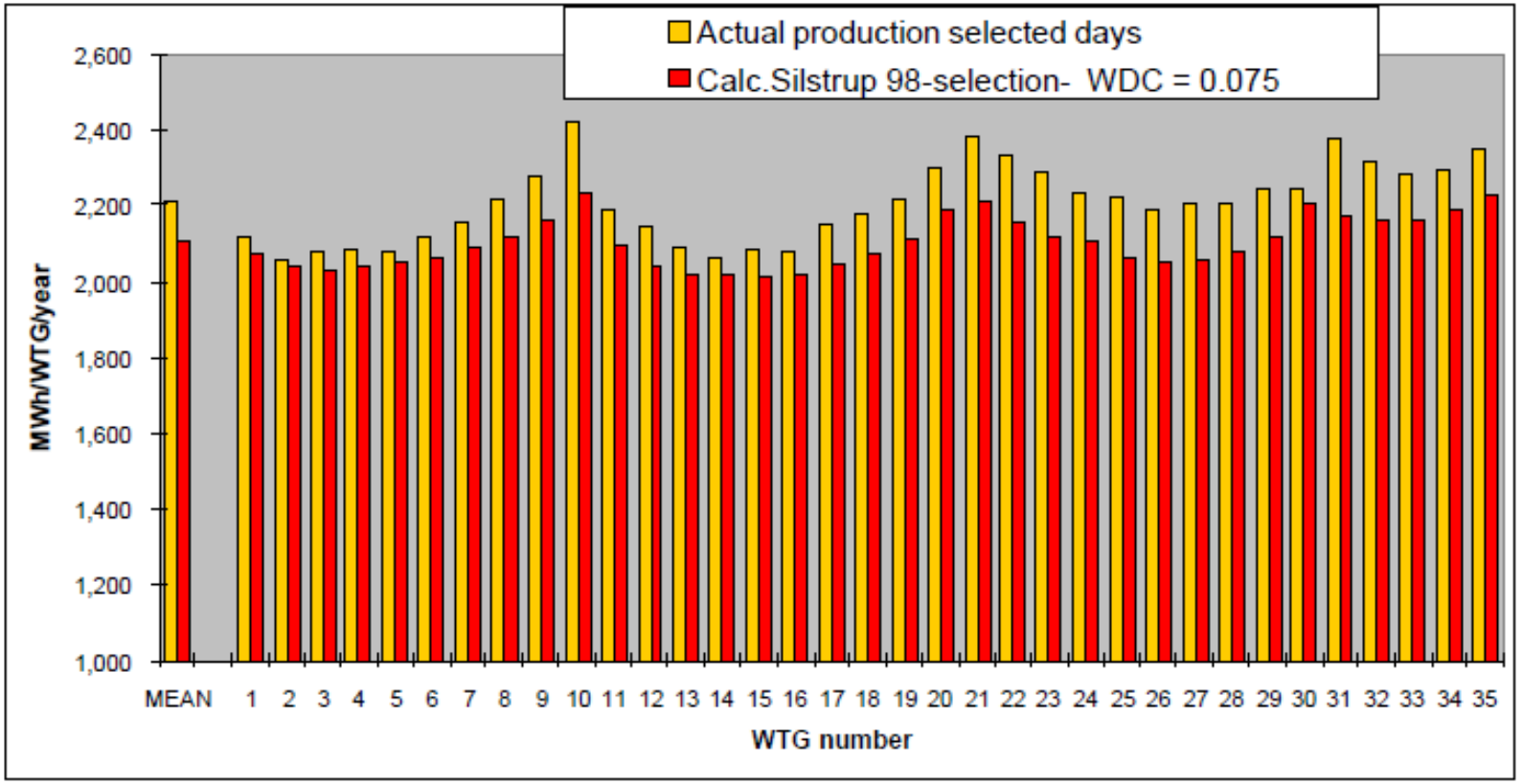
Variation of WDC –Standard DK wind statistic



Varying the Wake Decay Constant (WDC) gives quite large changes. With WDC = 0.1 the PARK efficiency increase from 0.885 to 0.905 – 2 %. But at 0.04, which normally is recommended for offshore, the park efficiency decrease to 0.845, which is 4% lower than standard. From the figure above, it is difficult clearly to see what the correct value will be. We therefore continue with a shorter, but more reliable data period.

Case study: Klim, Denmark

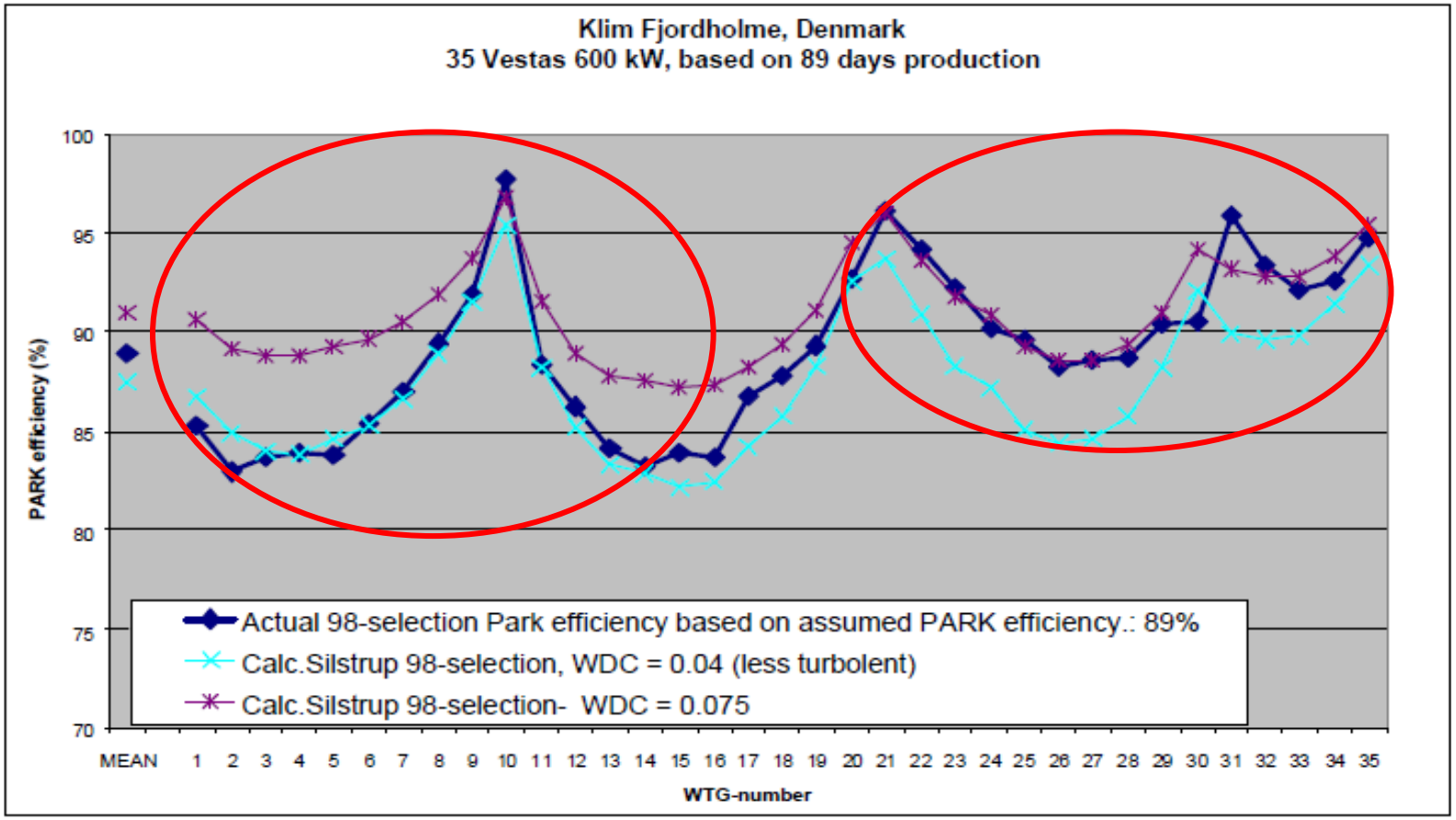
Calculation based on parallel selection of Wind and WTG production data



Here we see a much more "soft" set of graphs. But we also se a clear tendency in that the higher WTG number (more south-west), the higher production relative to calculation.

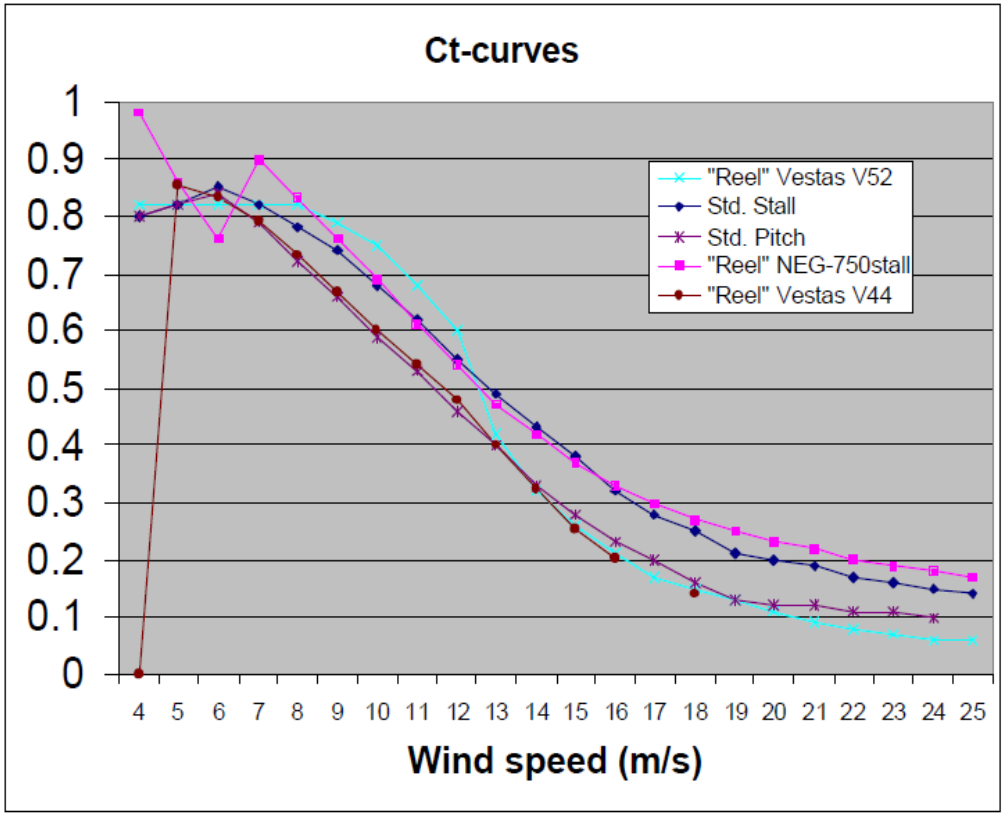
Case study: Klim, Denmark

- 前半段WDC=0.04較吻合,後半段WDC=0.075較吻合

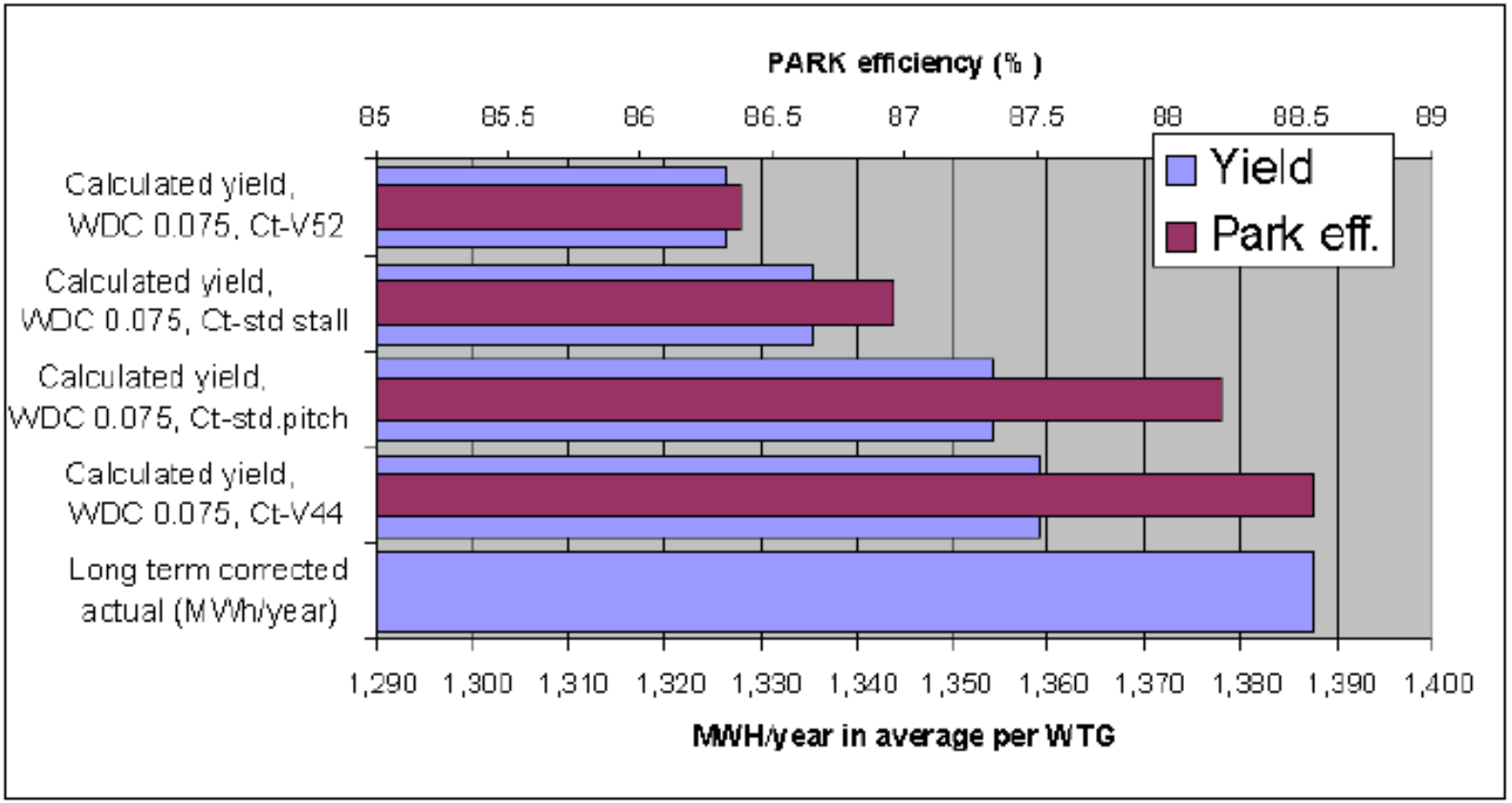


Case study: Klim, Denmark

- "real" Vestas V44 is very close to the "Standard pitch“
- V52 has much higher values for 8-12 m/s – even higher than the Stall curves
- The Standard Stall is compared with the NEG Micon 750 kW. These are almost identical, except from the region 4-8 m/s, where the 2-generator system makes the real curve toggle more.

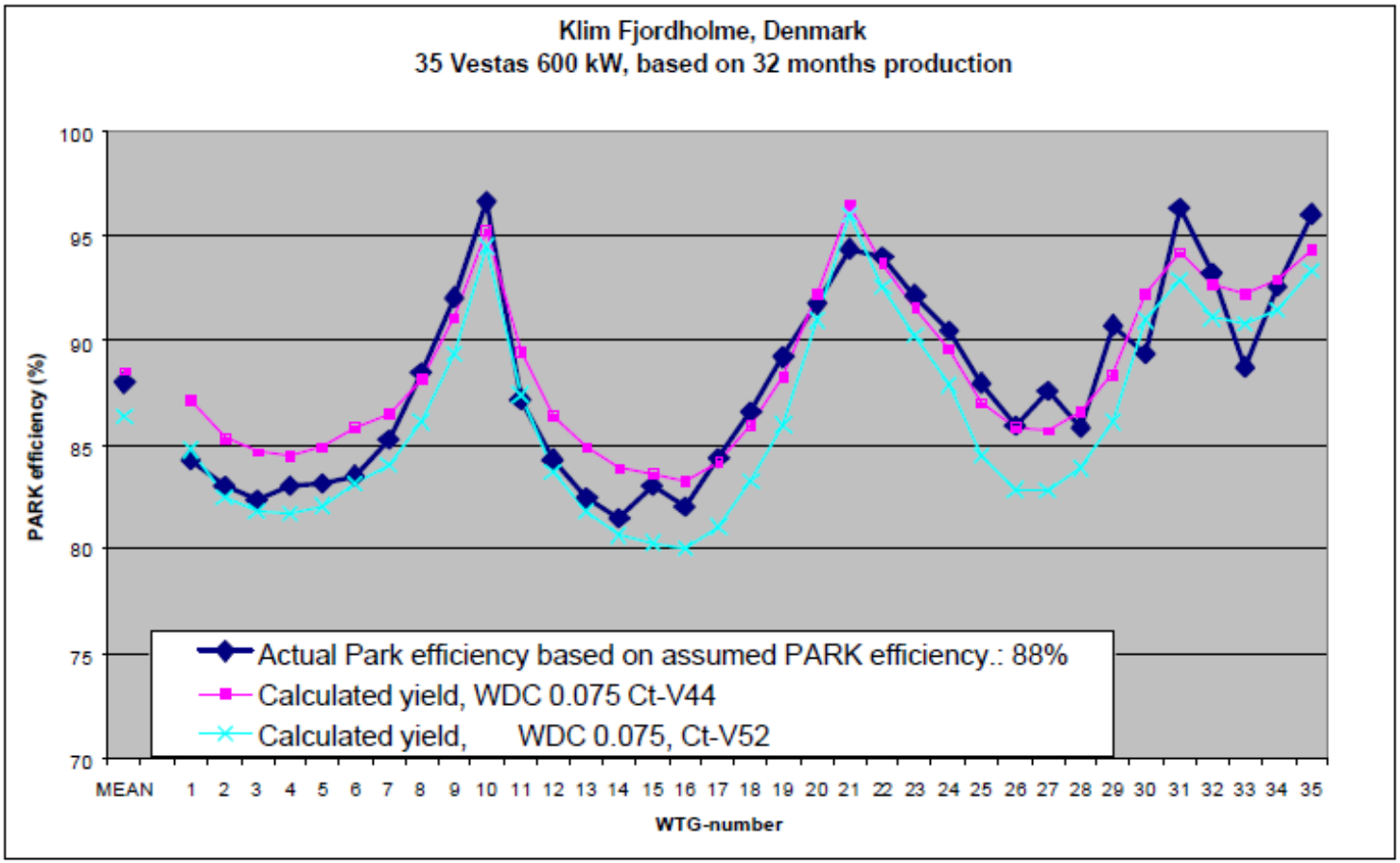


Case study: Klim, Denmark



It is seen that the "real" V44 Ct curve perform best relative to actual production, but this can be a coincidence since the differences are very small, far below the uncertainties.

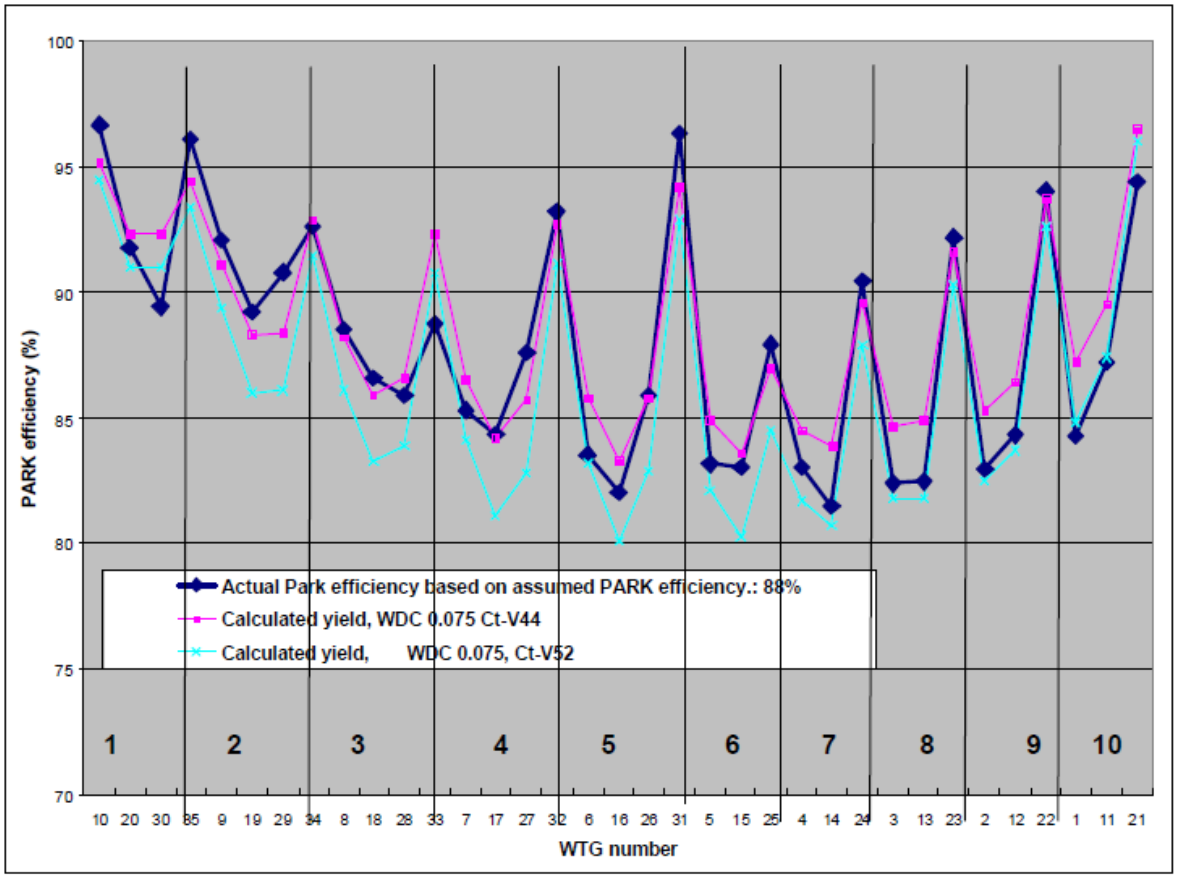
Case study: Klim, Denmark



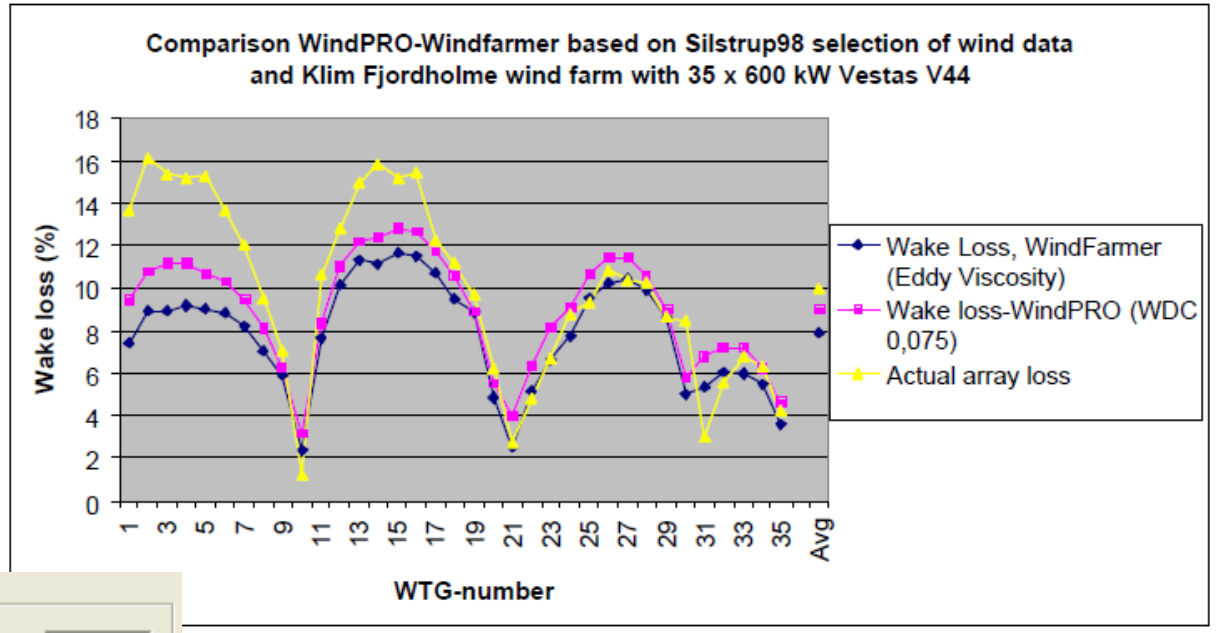
We se the same trends as by varying the WDC – the back rows, relative to main wind direction, WTG no. 1-20, follow the pattern from the most reducing Ct curves best, while the front rows relative to main wind direction follow the less reducing better.

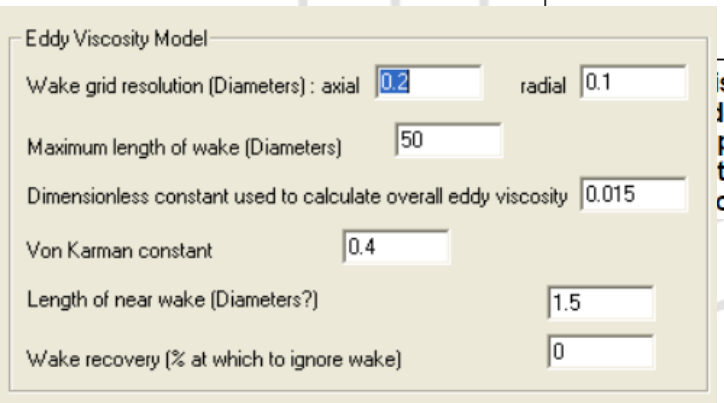
Case study: Klim, Denmark

- Here it is even clearer, that the back rows (assumed prevailing West-northwest wind) follow the most reducing Ct curve very well. Comparing to the below shown comparison by calculating with different WDC, we have to admit that adjusting the Ct value to a more reducing value gives a better match to actual production for the 5 eastern rows that adjusting the WDC.



Case study: Klim, Denmark





iscosity model in the standard set up perform poorer than the N. O.
del (used in WindPRO and WAsP) in standard set-up based on the Klim test data. It
percent point less losses than WindPRO, where it is obvious that the real losses is
thoug the wake losses not can be measured direct, the patterns gives a quite good
oss level were decreased 1 percent point, WTG 10 would have no Wake loss at all.

Thank You for Listening!

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