Workshop on Status and Development of Software Tools for PV Hybrid and Mini-grid Systems, organized by IEA PVPS Task 11 on PV Hybrids and Mini-grids:

HySyS, Hybrid Power System Balance Analyser

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Valencia, September of 2008

Background

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Perspectives

Background

- first steps at the Brazilian Wind Energy Centre (CBEE):

  Costa A. Methodology for Analysis and Project of Wind-Solar-Battery Hybrid Power Systems (in Portuguese). MSc Thesis, UFPE/CBEE, 2001.

- further development at CIEMAT:

  Costa et al. HySyS v.1.0 - Hybrid Power System Balance Analyser. Proceedings of European Wind Energy Conference, Madrid, 2003.

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Objective

developing a tool (HySyS) for sizing and long-term analysis of isolated hybrid systems, being the main features of the tool:

- automaticity for non-expert users;
- clarity in the comparison between renewable and non-renewable solutions;
- flexibility for changes by non-expert users.

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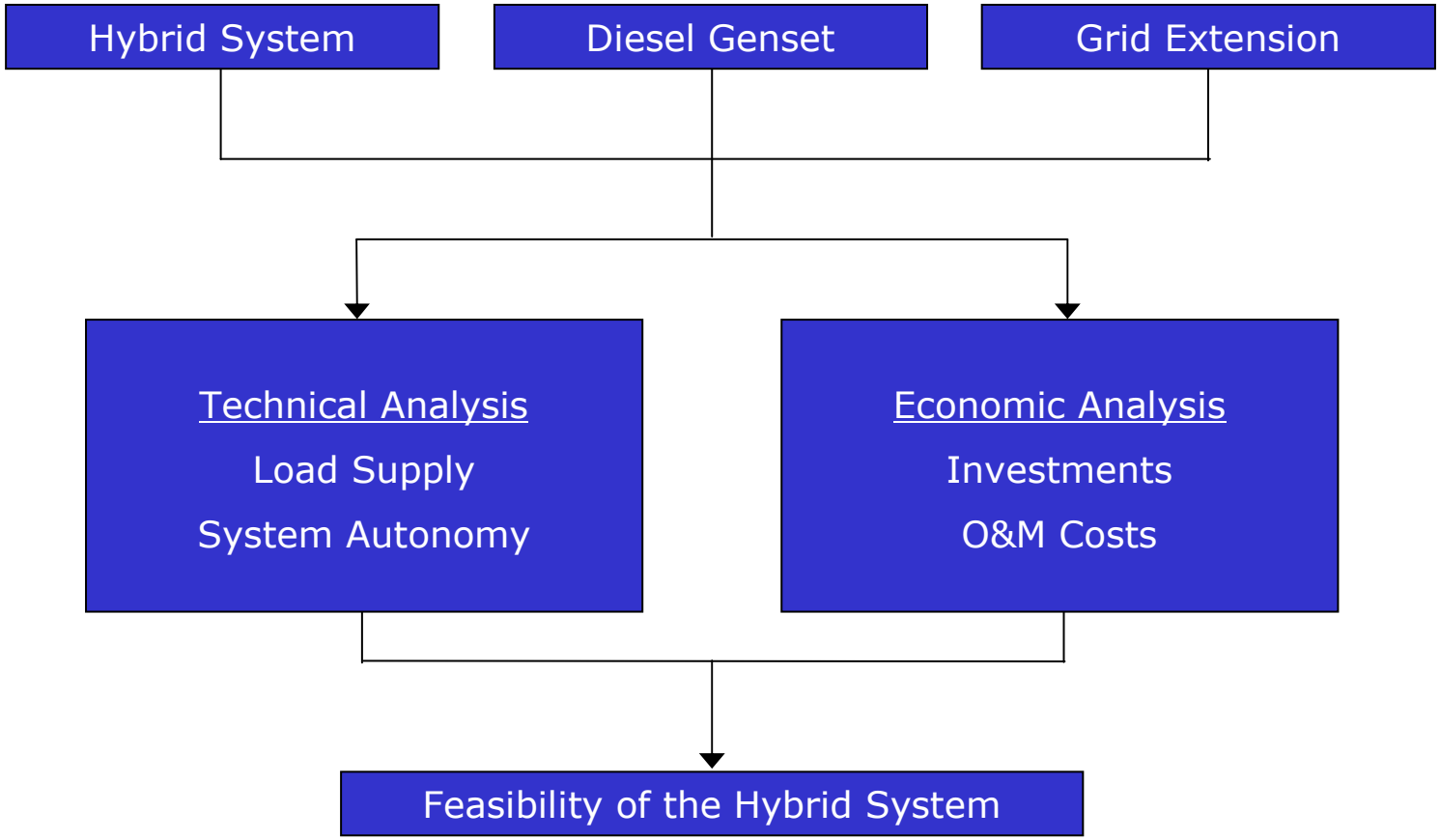
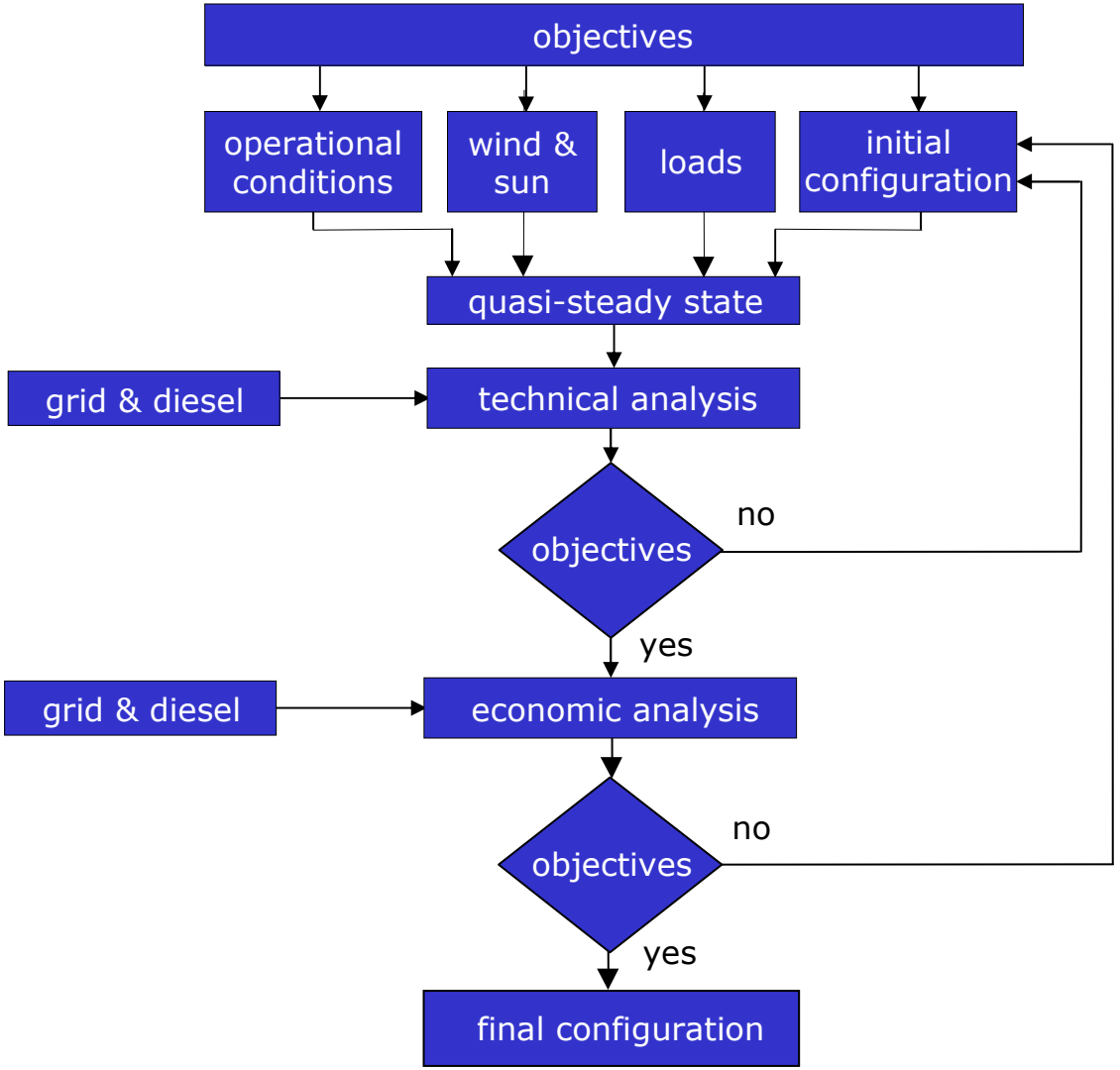
Methodology

General Diagram



Methodology

Detailed Diagram



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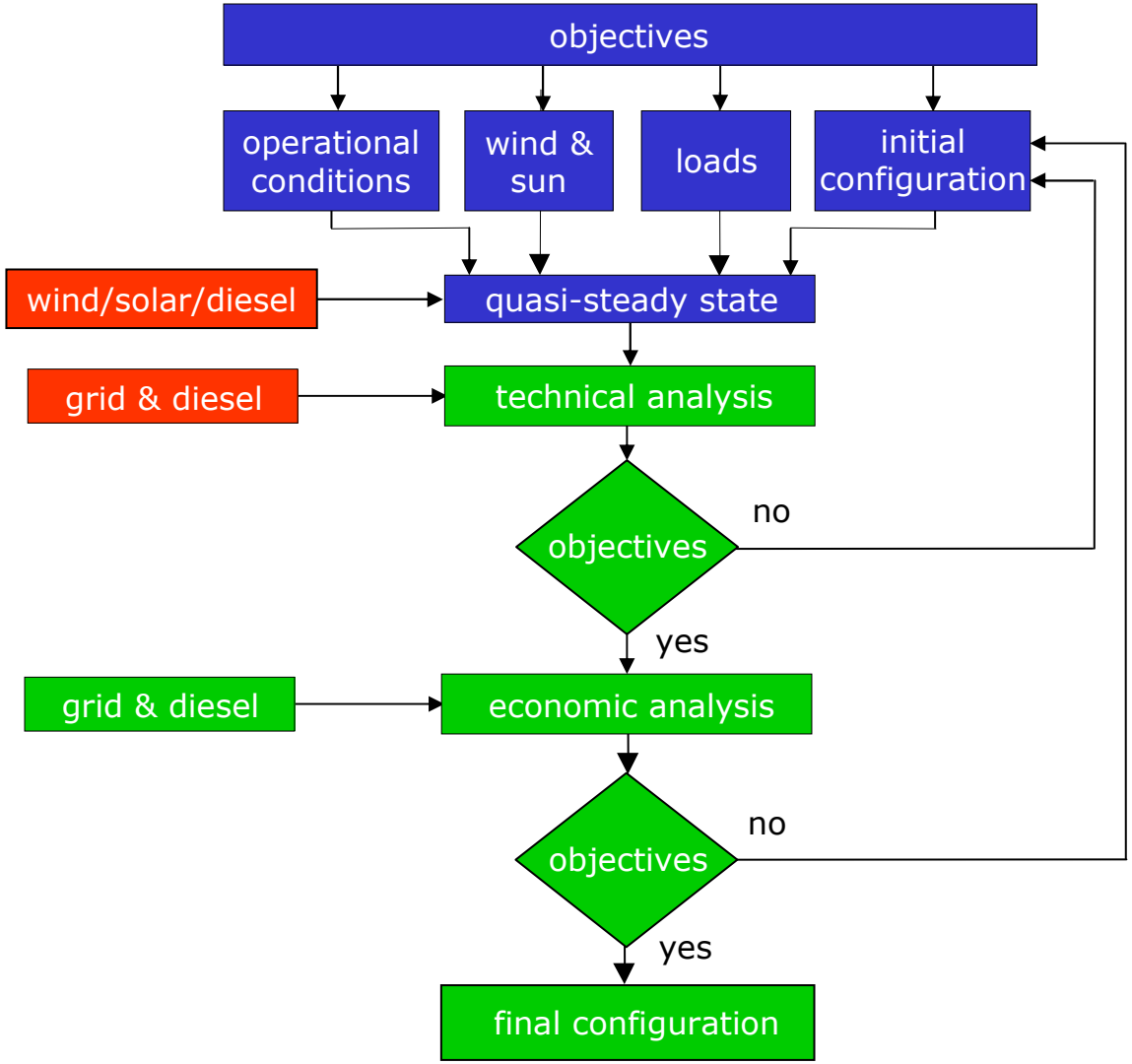
Actual Status



implemented in MATLAB

implemented in Excel

Hybrid2/Homer

The wind/solar/battery is already implemented in MATLAB.
But, the wind/solar/diesel is not implemented yet.

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Validation

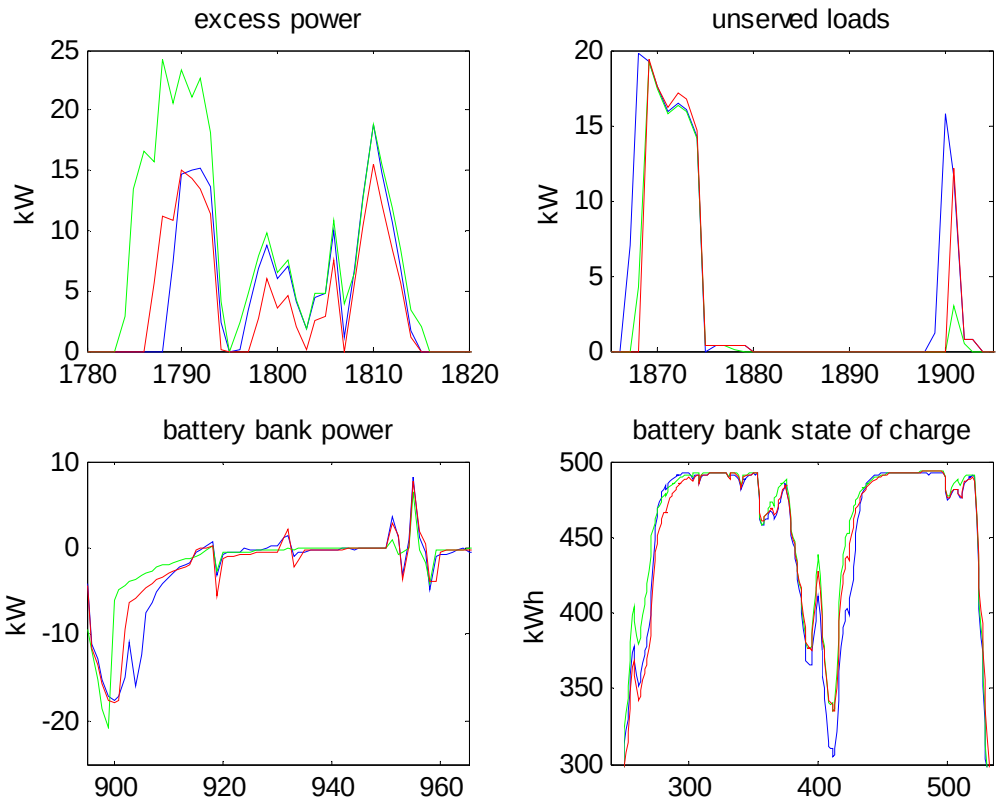
<u>models</u>

wind turbine:
Manwell et al., 1996
Costa, 2001

photovoltaic panel:
Green, 1986
Lorenzo, 1994

lead-acid battery:
Manwell et al., 1996

The Xcalac Case Study, figures extracted from Costa et al. (2003)



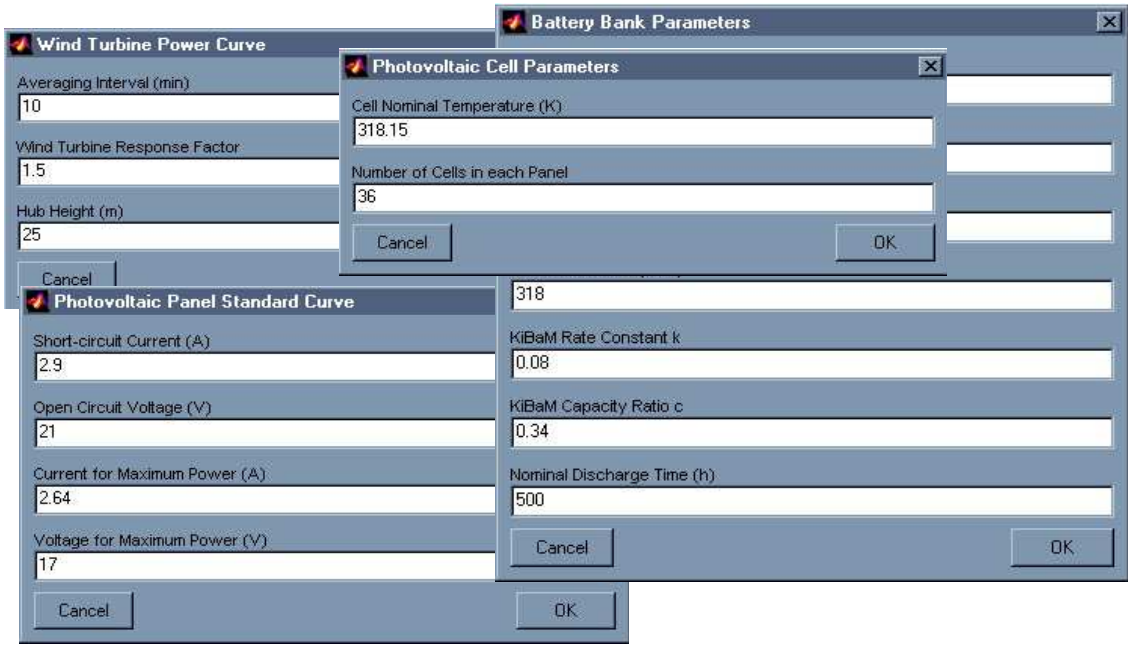
blue – Hybrid2 (Manwell et al, 1996)
green – Homer (Lilienthal and Lambert, 2000)
red – HySyS (Costa et al., 2003)

Main Features

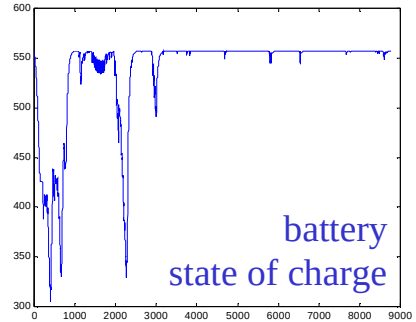
Automaticity

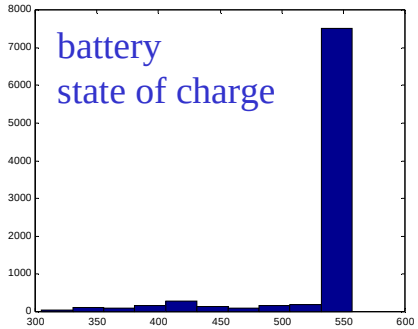
HySyS

input



output

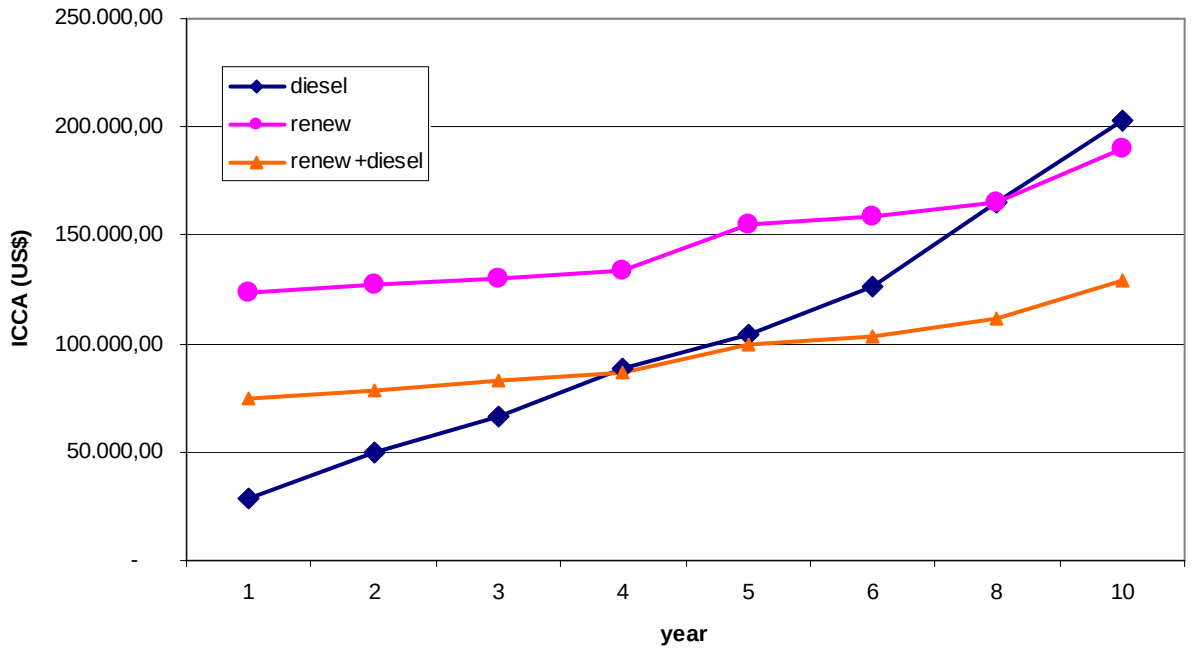




Main Features

Clarity

ICCA = investments plus O&M costs at constant cumulated prices



Main Features

Flexibility

```
...
if bsto(i-1)>=bmax % Battery Bank Total Storage (kWh)
    if nt(i)==0
      ex(i)=0; % Excess Power (kW)
      bpw(i)=0; % Battery Power (kW), Positive for Outgoing Power and Negative for Incoming Power
      unspl(i)=0; % Unserved Primary Load (kW)
      bsta(i)=bsta(i-1);
      bstb(i)=bstb(i-1);
      bsto(i)=bsta(i)+bstb(i);
    end
    if nt(i)>0
      ex(i)=0;
      % Maximum Allowable Battery Bank Discharge (kW)
      maxdch=((bsta(i-1)*kik*exp(-kik*t))+(bsto(i-1)*kik*kic*(1-exp(-kik*t))))/(1-exp(-kik*t)+kic*(kik*t-1+exp(-kik*t)));
      if nt(i)>=maxdch
        bpw(i)=maxdch;
        unspl(i)=nt(i)-bpw(i);
      else
        bpw(i)=nt(i);
        unspl(i)=0;
      end
      bsta(i)=(bsta(i-1)*exp(-kik*t))+((bsto(i-1)*kik*kic-bpw(i))*(1-exp(-kik*t))/kik)-(bpw(i)*kic*(kik*t-1+exp(-kik*t))/kik);
      bstb(i)=(bstb(i-1)*exp(-kik*t))+(bsto(i-1)*(1-kic)*(1-exp(-kik*t)))-(bpw(i)*(1-kic)*(kik*t-1+exp(-kik*t))/kik);
      bsto(i)=bsta(i)+bstb(i);
    end
    if nt(i)<0
      ex(i)=-nt(i);
      bpw(i)=0;
      unspl(i)=0;
      bsta(i)=bsta(i-1);
      bstb(i)=bstb(i-1);
      bsto(i)=bsta(i)+bstb(i);
    end
    ...
```

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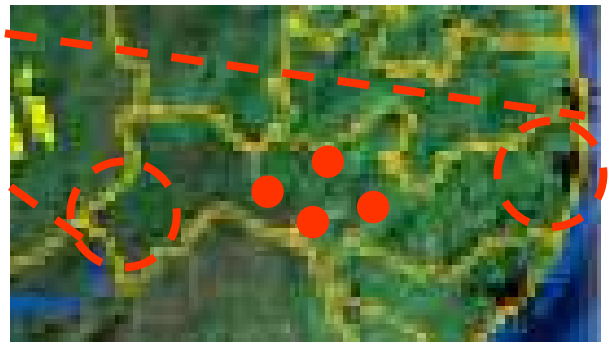
General Objective



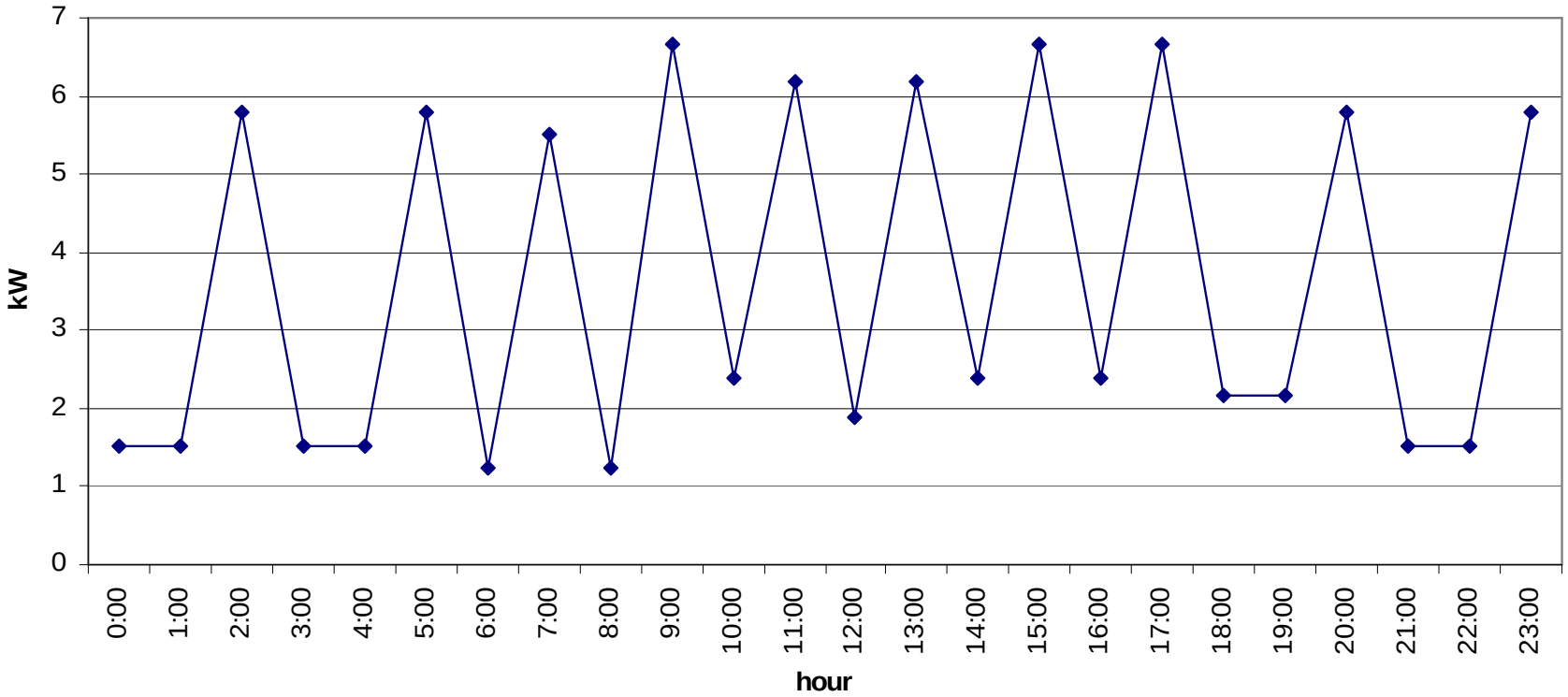
open circles = metropolitan regions
closed circles = cell phone stations

Specific Objectives

Priorities:

1. 0% of unmet load for:
   1 omni ERB with 14 TRX; 10 channels/TRX; ~10W/channel
2. minimisation of the maintenance tasks
3. initial investment smaller than US$100,000.00
4. relatively constant O&M costs

Daily Profile



Simulation with Homer

Purely Renewable
(simulation period = 1 year)

Loads	
mean [1]	3.58 kW
minimum [1]	1.24 kW
maximum [1]	6.66 kW
annual demand [1]	31,343.57 kWh
unmet load [1]	0% [2]
excess	62% [3]

yes → **priority 1**

Production	
wind turbines	93% [3]
pv panels	7% [3]
total production	91,175 kWh

Battery Bank	
flow	4,648 kWh
effective lifetime	5 years

yes → **priority 2**

[1] w.r.t. all primary loads; [2] w.r.t. annual demand; [3] w.r.t. total production.

Simulation with Homer

Renewable with Diesel
(simulation period = 1 year)

Loads	
mean [1]	3.58 kW
minimum [1]	1.24 kW
maximum [1]	6.66 kW
annual demand [1]	31,343.57 kWh
unmet load [1]	0% [2]
excess	26% [3]

yes → **priority 1**

Production	
wind turbines	88% [3]
pv panels	4% [3]
diesel genset	8% [3]
total production	48,308 kWh

Battery Bank	
flow	7,505 kWh
effective lifetime	5 years

yes → **priority 2**

[1] w.r.t. all primary loads; [2] w.r.t. annual demand; [3] w.r.t. total production.

Simulation with Homer

Diesel Genset
(simulation period = 1 year)

Production	
total production	34,641 kWh
fuel consumption	16,077 litres
especific consumption	0.464 litre/kWh
unmet load [1]	0% [2]
excess	5% [3]
minimum output	2.10 kW
maximum output	6.99 kW
mean output	3.95 kW
effective lifetime	1,7 year
number of starts	1

yes → **priority 1**

no → **priority 2**

[1] w.r.t. all primary loads; [2] w.r.t. annual demand; [3] w.r.t. total production.

Purely Renewable

CIF Values plus Installation, Pernambuco, Brazil, year 2000

component	quantity	unity (US$)	subtotal (US$)
turbine and tower [1]	02	23,750.00	47,500.00
central controller [1]	01	10,000.00	10,000.00
pv panel	35	850.00	29,750.00
battery bank	01	18,000.00	18,000.00
converter	01	8,330.00	8,330.00
diesel backup and tank	01	7,000.00	7,000.00
total inversion (US$)			120,580.00

[1] imported equipment

no

priority 3

Renewable with Diesel

CIF Values plus Installation, Pernambuco, Brazil, year 2000

component	quantity	unity (US$)	subtotal (US$)
turbine and tower [1]	01	23,750.00	23,750.00
central controller [1]	01	10,000.00	10,000.00
pv panel	10	850.00	8,500.00
battery bank	01	9,000.00	9,000.00
converter	01	13,328.00	13,328.00
diesel and tank	01	6,000.00	6,000.00
total inversion (US$)			70,578.00

[1] imported equipment

yes

priority 3

Diesel Genset

CIF Values plus Installation, Pernambuco, Brazil, year 2000

component	US$
diesel and tank	7,000.00
rectifier	4,998.00
total inversion	11,998.00

yes

priority 3

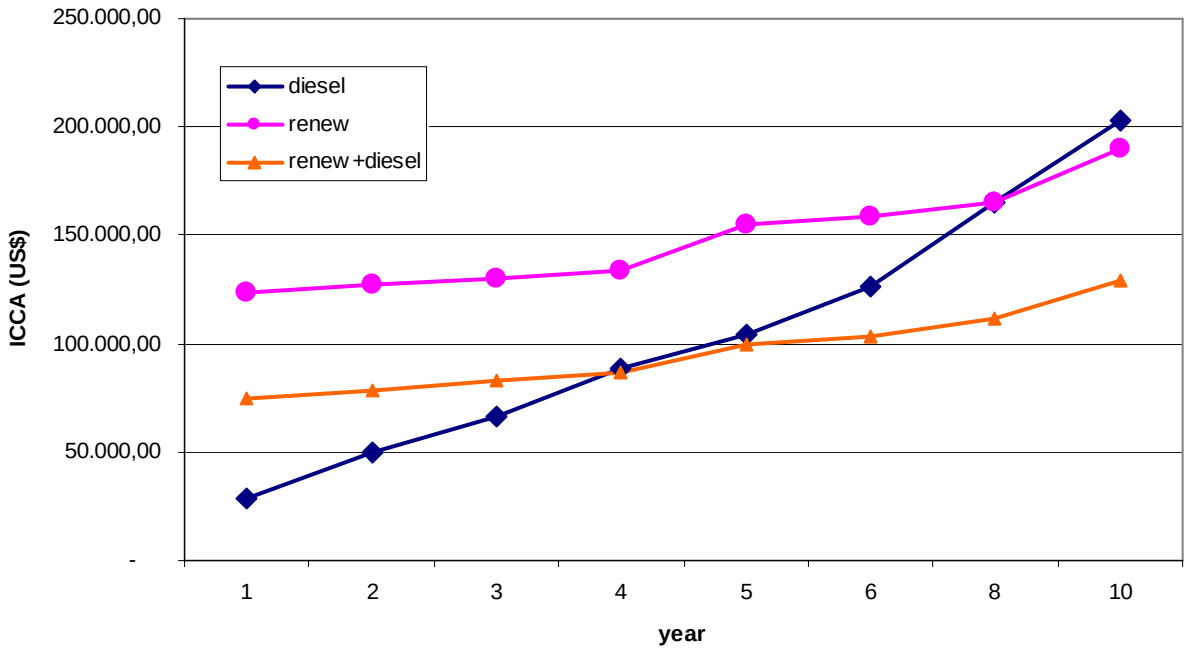
Grid Extension

CIF Values plus Installation, Pernambuco, Brazil, year 2000

component	US$
km of 3-phase LD	4,500.00
SE 30 kVA	1,400.00
low voltage connection	205.00
low voltage measurement	215.00

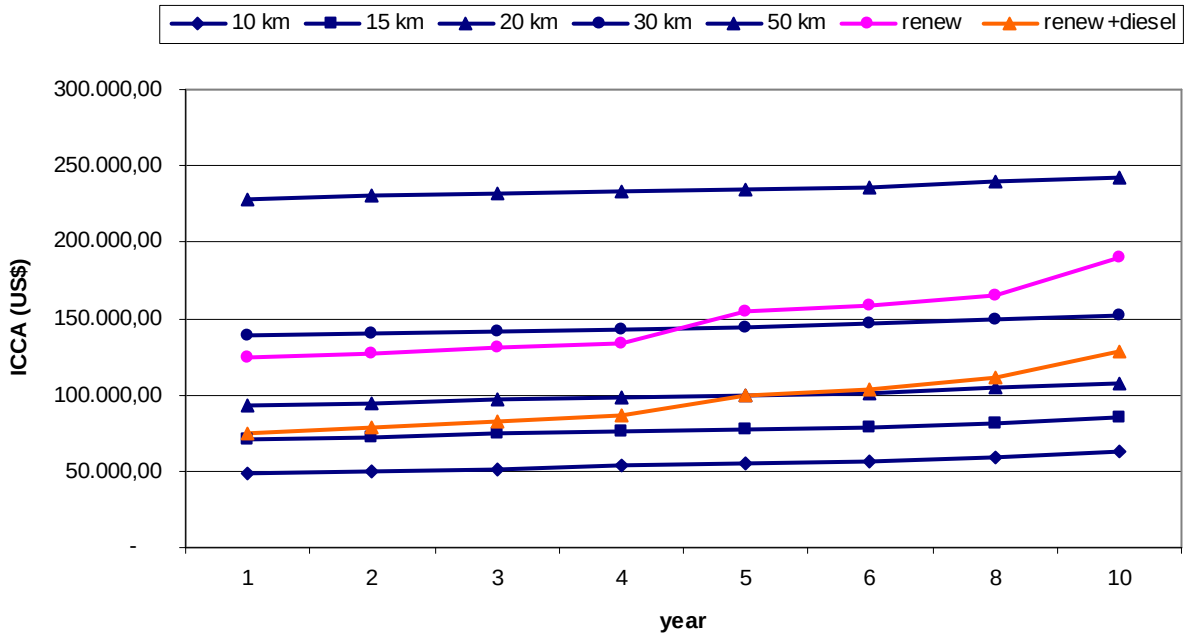
Comparing with the Diesel Genset

ICCA = investments plus O&M costs at constant cumulated prices



Comparing with the Grid Extension

ICCA = investments plus O&M costs at constant cumulated prices



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HySyS ‘short-term’ tasks:

- inclusion of the diesel genset;
- transcription from EXCEL to MATLAB;
- inclusion of a database of commercial models;
- improvement of the graphical interface;
- economic analysis with non-constant cumulated prices;
- economic analysis considering, for instance, specific financing lines for renewable energy.

Thank you very much
for your Attention!

Questions and/or Comments:

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