

Research Group Meeting, 07/12/2009

Summary of Previous Works

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The University of Manchester

Overview of the Presentation

1. Summary of Research Interest 2. Design of Power System Software

- 2.1 Project ASP
- 2.2 Project SimSP

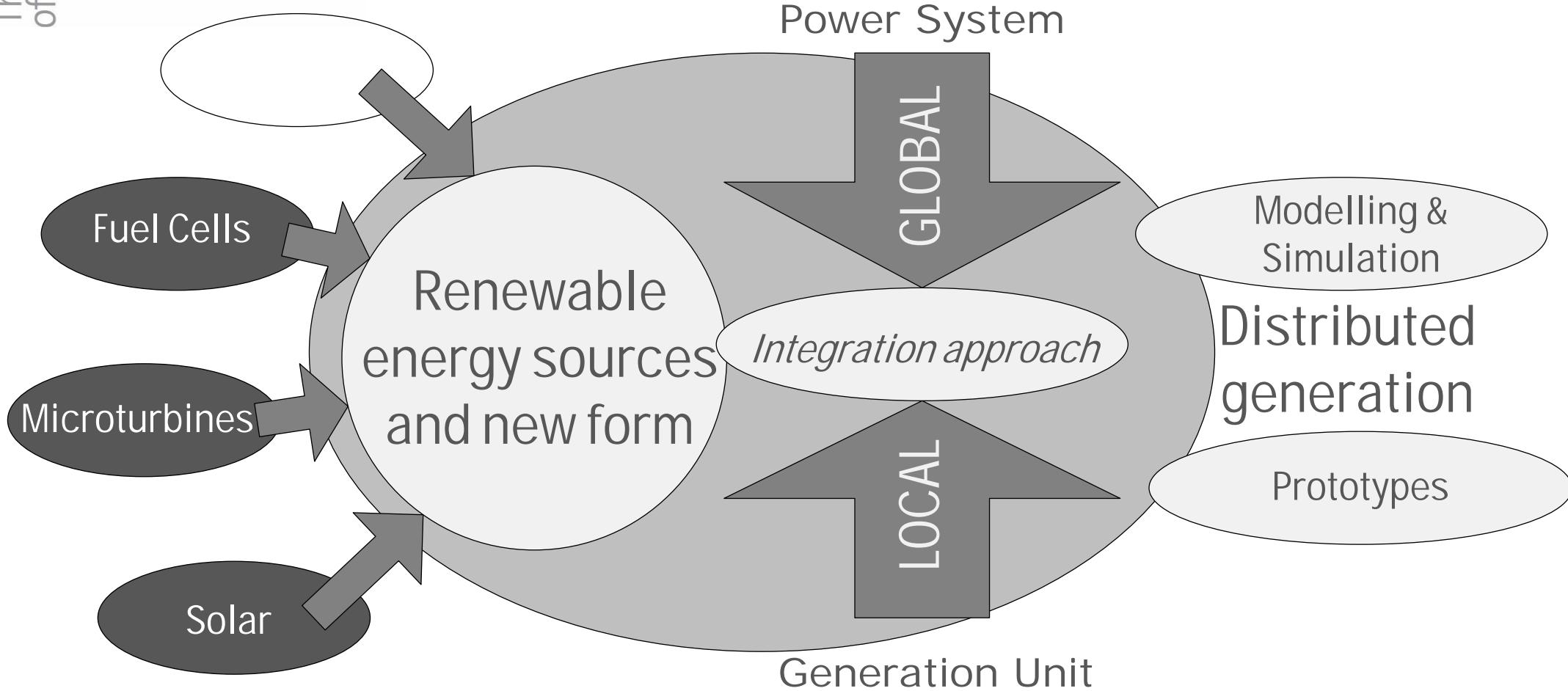
2. Wind Power

- 2.1 Resource Assessment and Project Evaluations
- 2.2 Development of Prototypes

1. Summary of Research Interest

1. Summary of Research Interest

New form of generation and Renewable Energy Sources



2. Design of a Power System Analysis Software

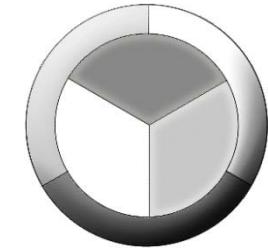
- 2.1. Project ASP**
- 2.2. Project SimSP**

2.1. Project ASP

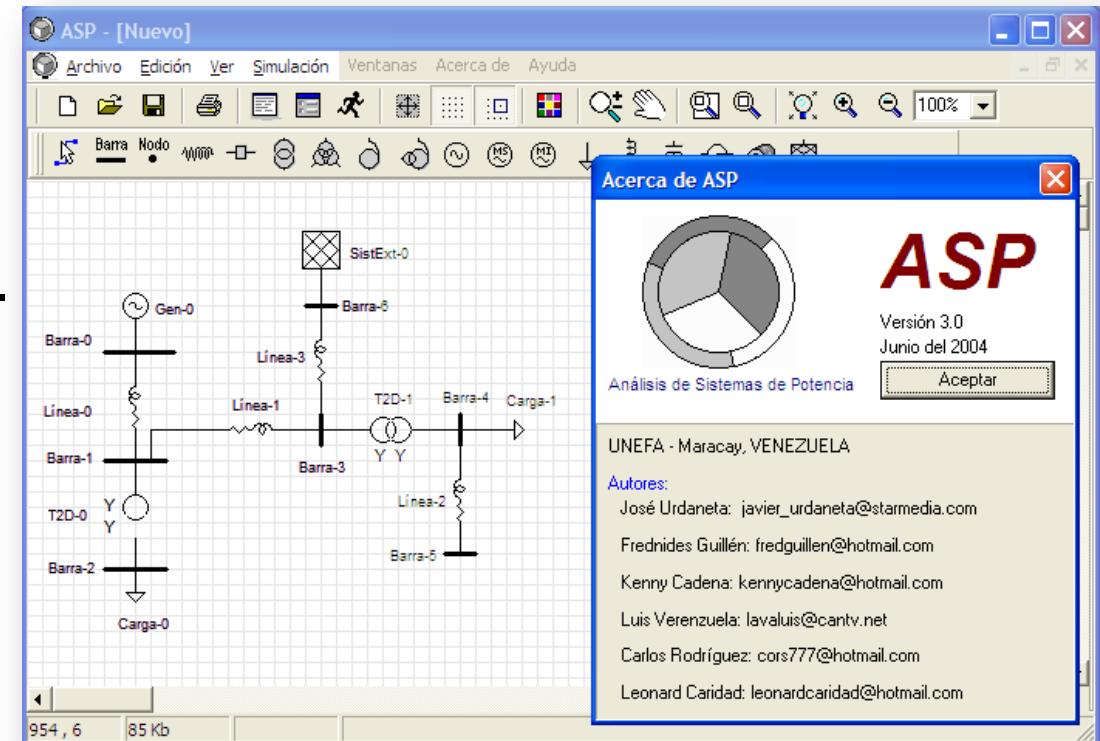
2.1. Project ASP

ASP

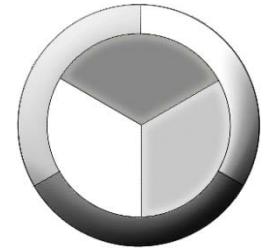
ANALIZADOR DE SISTEMAS DE POTENCIA



- Powerful Graphic Interface Unit.
- User friendly.
- Instinctive use.
- Flexible data base.
- Minimum system requirements.
- PC and MS Windows XP based.
- Analysis in transmission and distribution networks.



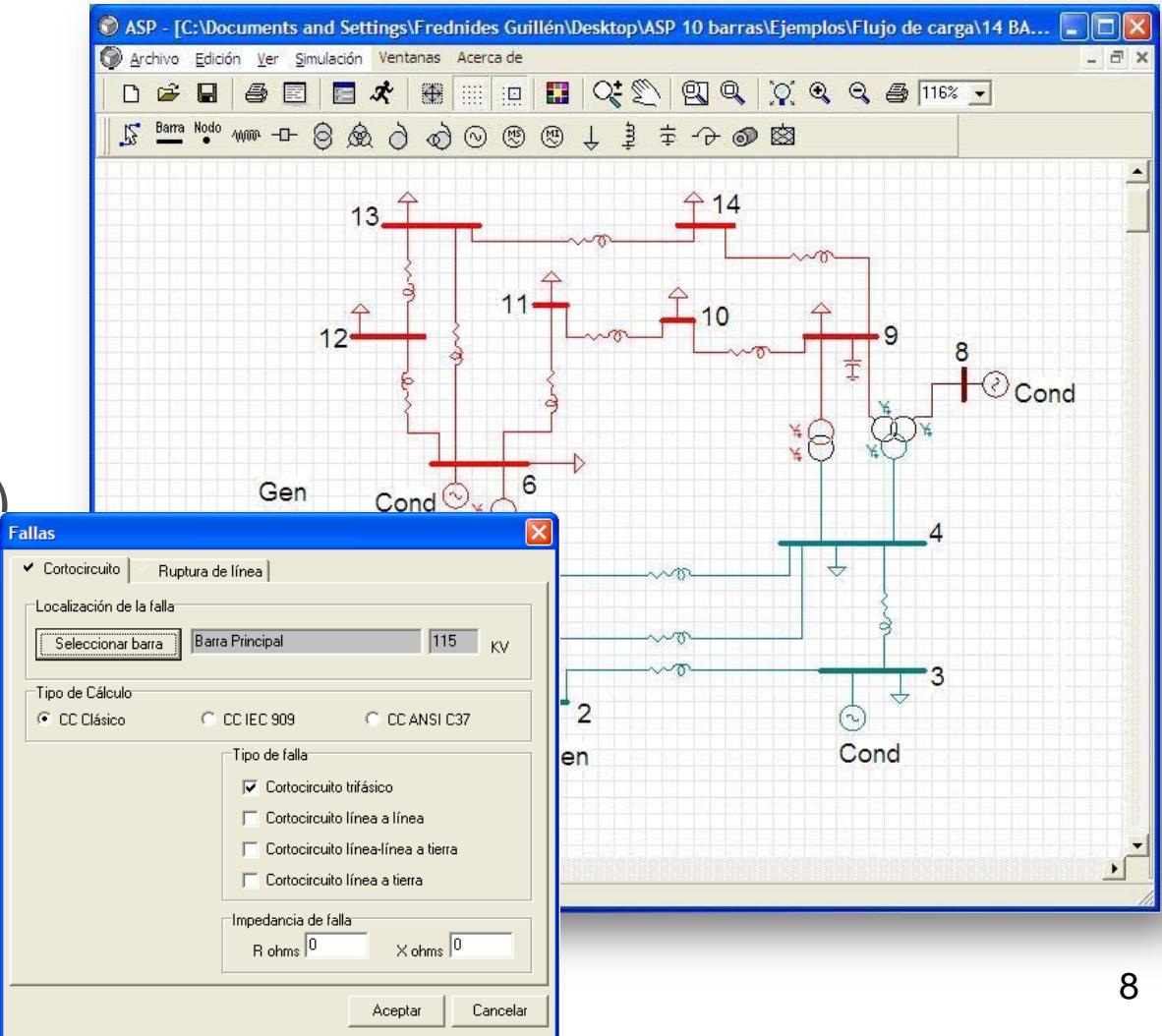
2.1. Project ASP



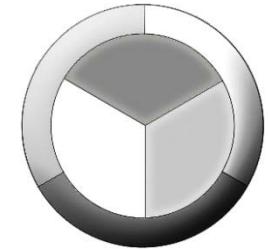
ASP

ANALIZADOR DE SISTEMAS DE POTENCIA

- Faulted system analysis
 - Series:
 - One line open
 - Two line open
 - Shunt (short-circuits)
 - Single phase (line-ground)
 - Two phase, Two-phase-ground, Tri-phase.
 - ANSI C57
 - IEC 60909



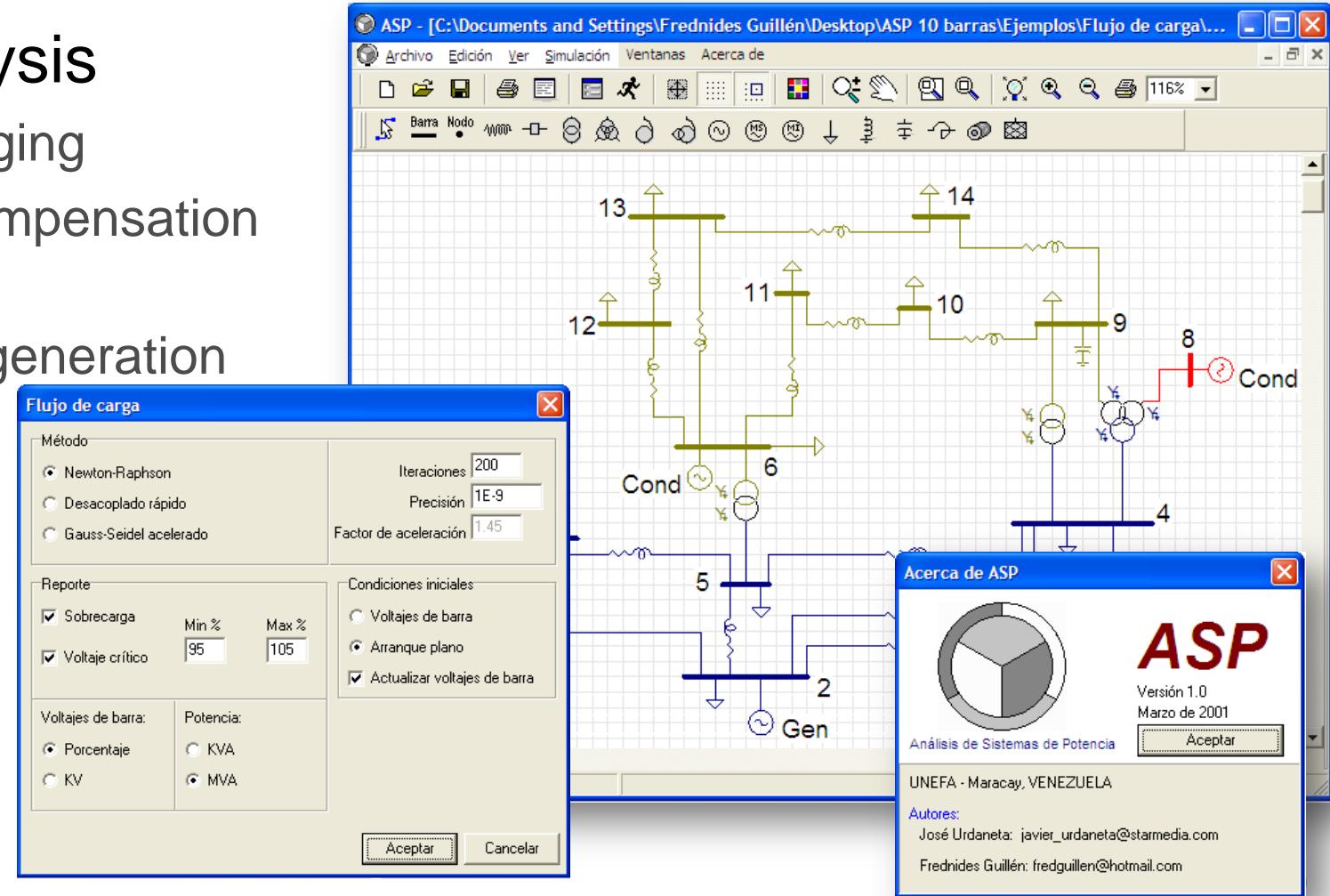
2.1. Project ASP



ASP

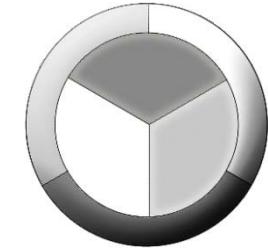
ANALIZADOR DE SISTEMAS DE POTENCIA

- Power Flow analysis
 - Transformer changing
 - Reactive shunt compensation (capacitors).
 - Reactive limits in generation units.
 - Static loads.
 - Dynamic loads.

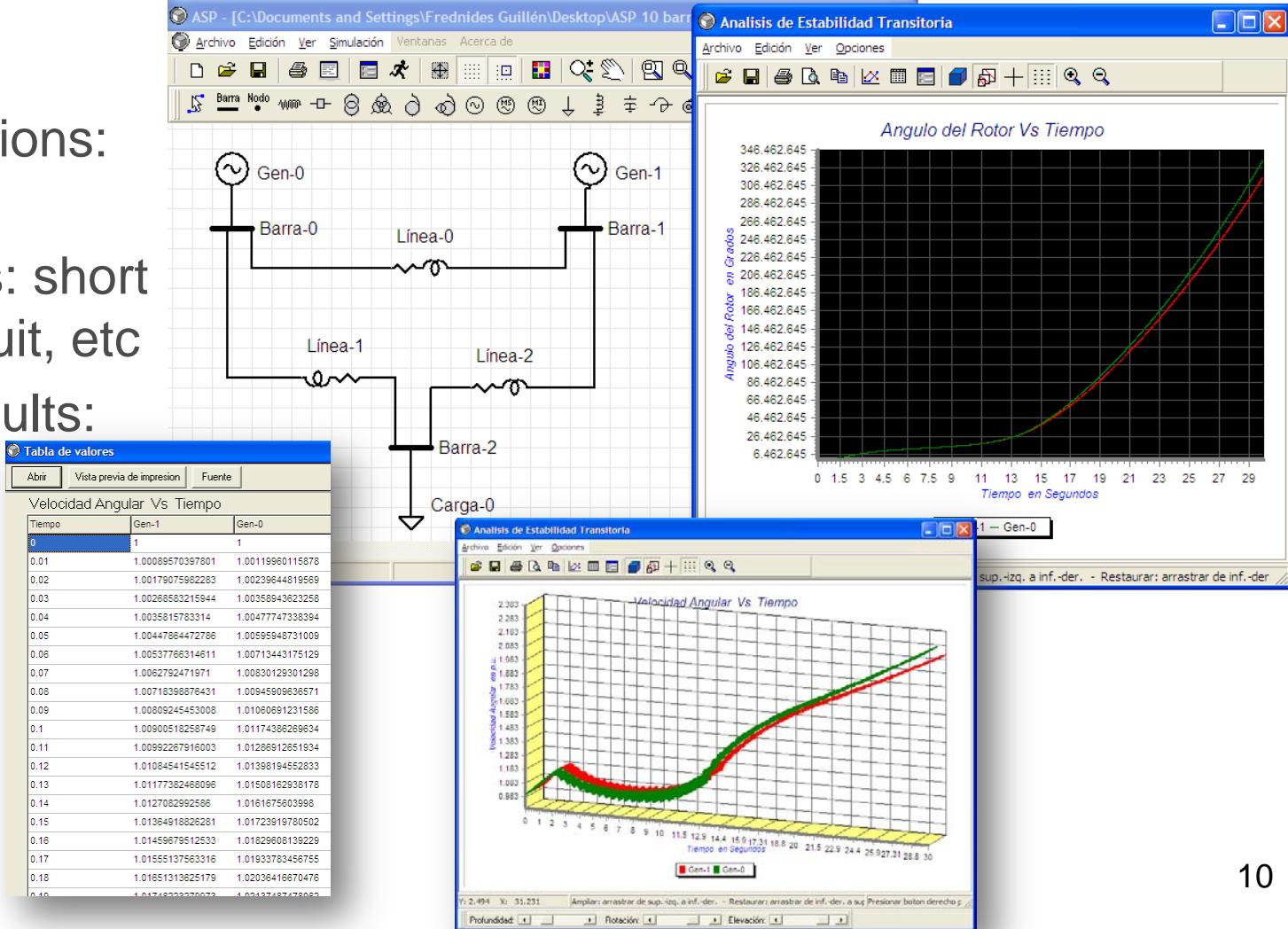


2.1. Project ASP

ASP ANALIZADOR DE SISTEMAS DE POTENCIA



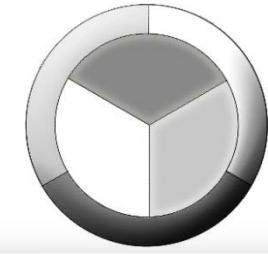
- Stability analysis
 - Time domain simulations: Runge-Kutta, Euler.
 - Several disturbances: short circuit (3f), open circuit, etc
 - Great flexibility in results: tables and graphs.



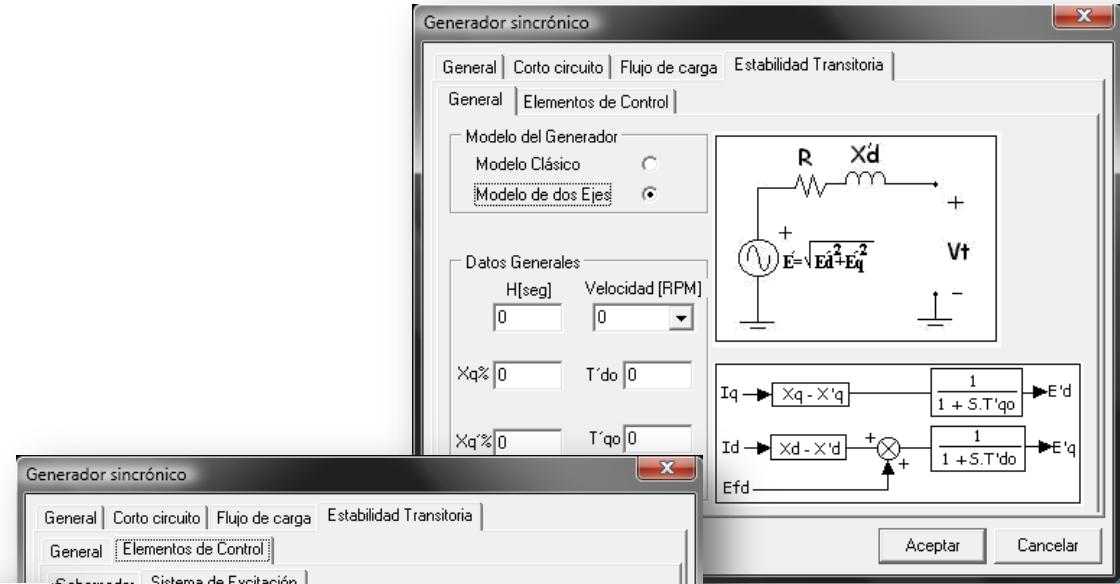
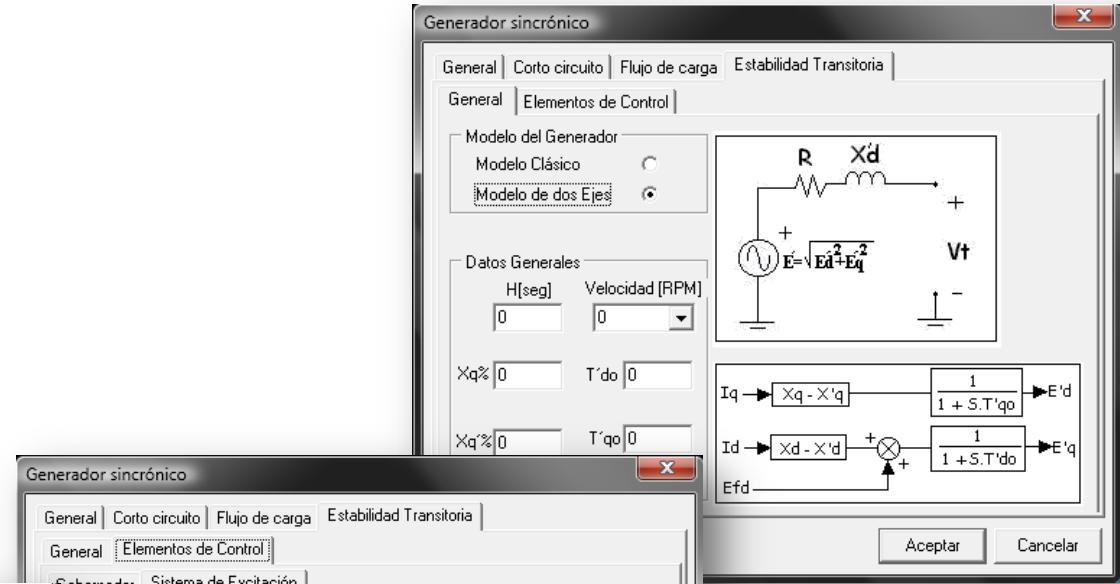
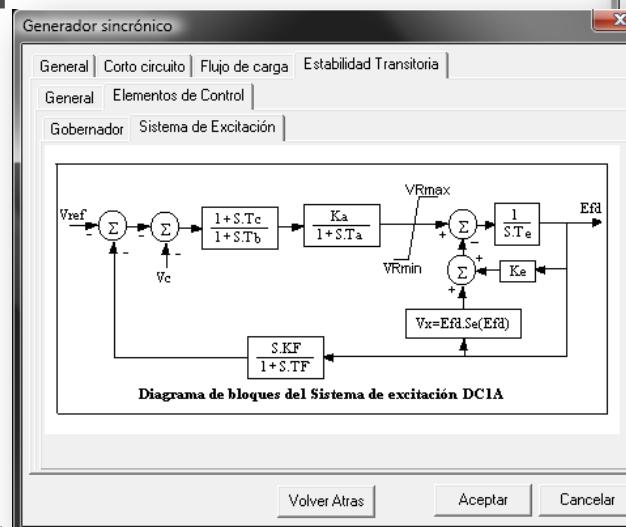
2.1. Project ASP

ASP

ANALIZADOR DE SISTEMAS DE POTENCIA



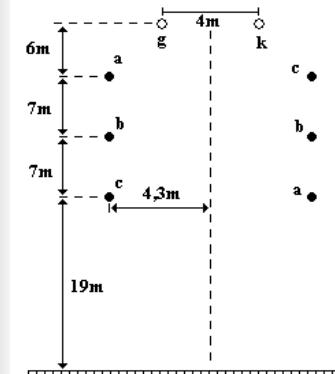
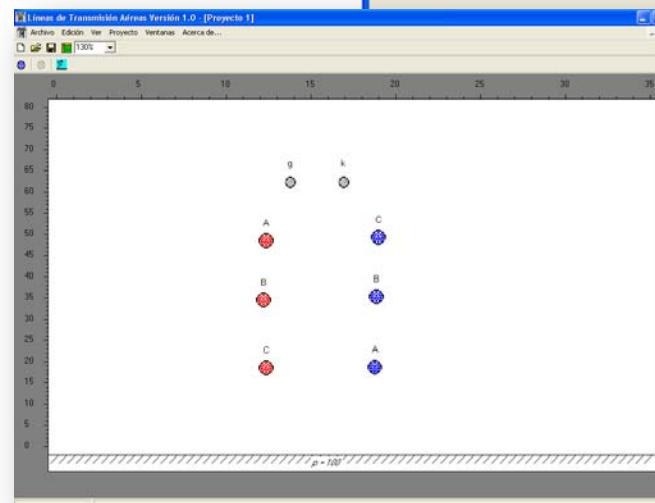
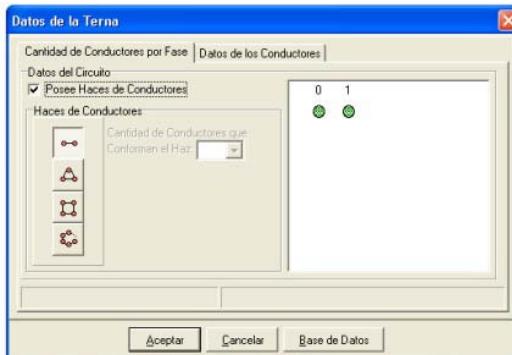
- Stability analysis
 - Generator controls: Exciter and governors
 - IEEE models
 - Typical parameter included.
 - Graphic representation.



2.1. Project ASP

Line Constant Calculation (MCCL)

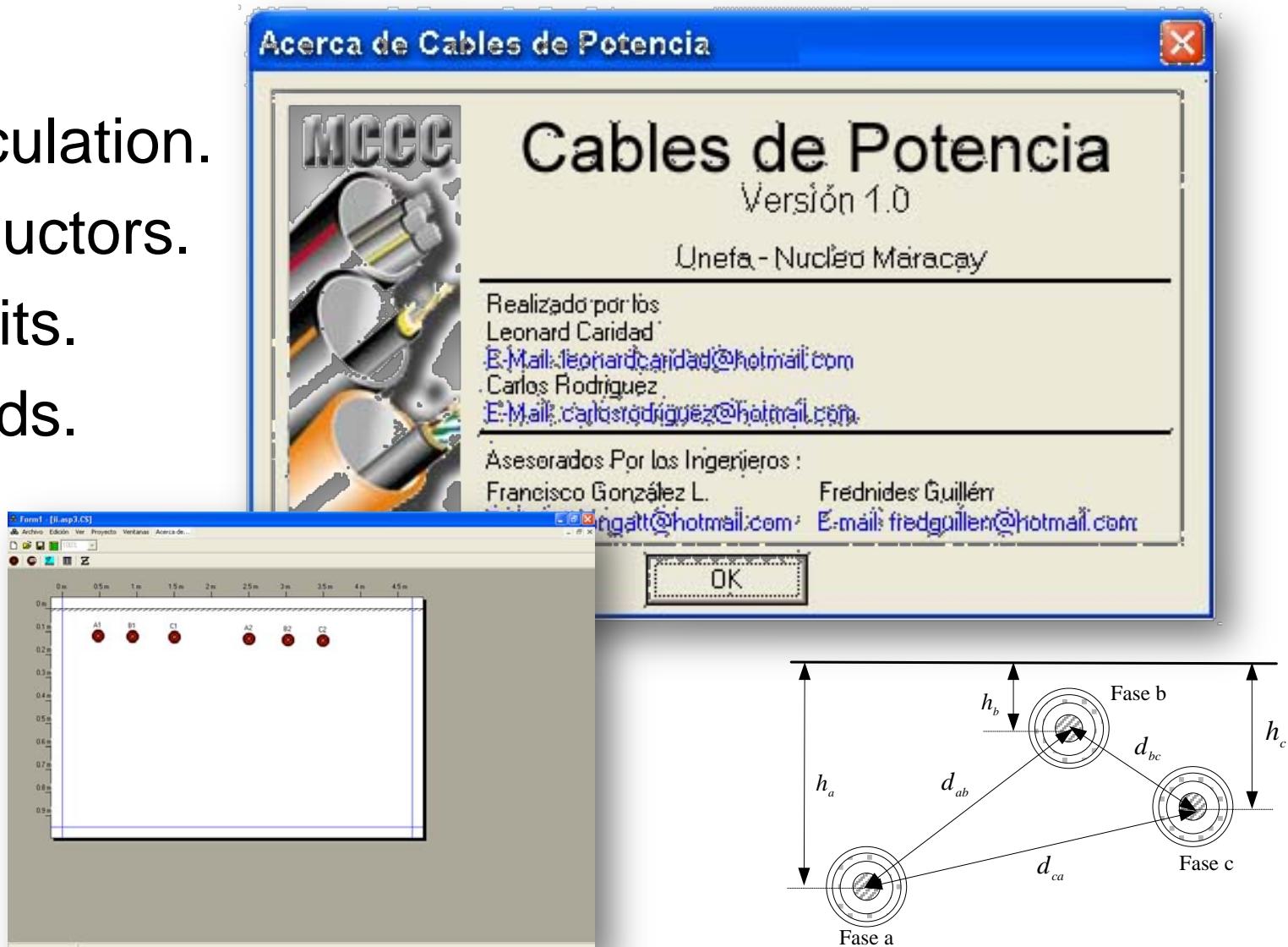
- Z_{abc} , Z_{012} calculation.
- Multiple conductors in bundle.
- Multiple circuits.
- Multiple ground wires.
- Earth return.



2.1. Project ASP

Cable Constant Calculation (MCCC)

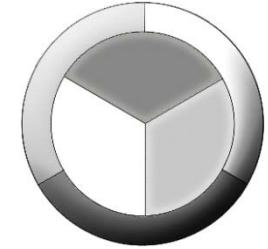
- Z_{abc} , Z_{012} calculation.
- Multiple conductors.
- Multiple circuits.
- Multiple shields.
- Earth return.



2.1. Project ASP

ASP

ANALIZADOR DE SISTEMAS DE POTENCIA

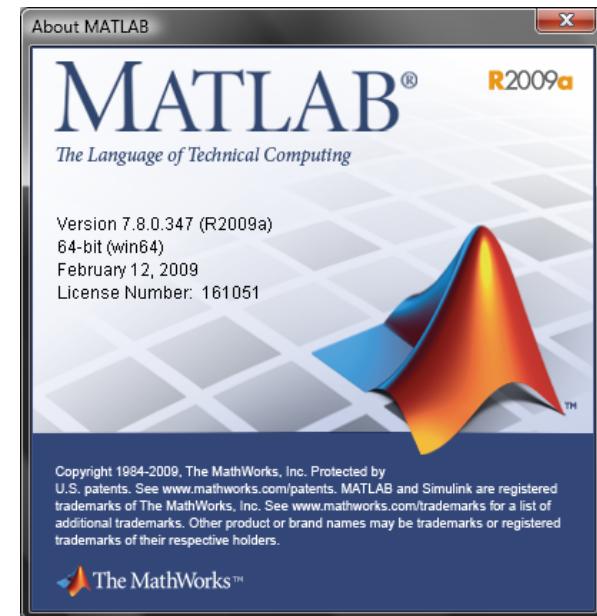
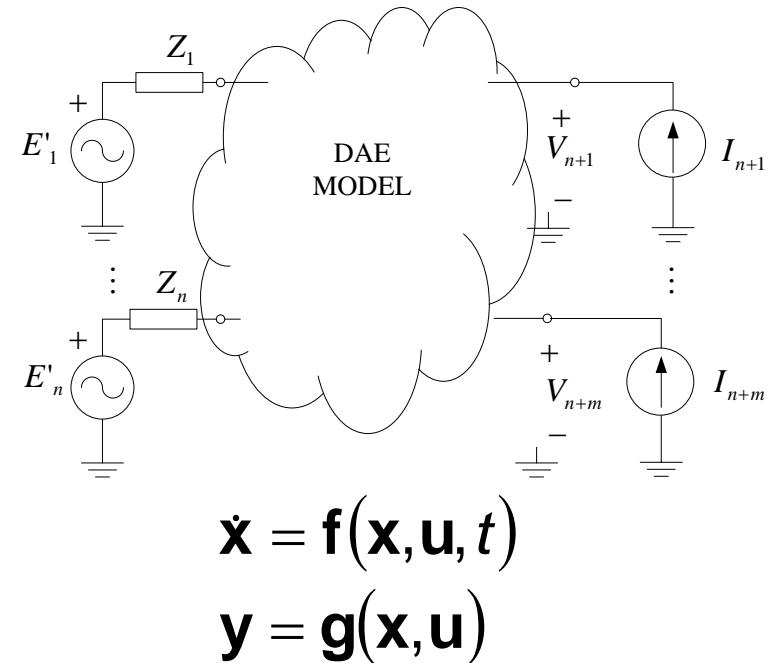


- Future improvement:
 - Harmonic load flow (this stage was covered developing algorithm and testing in MATLAB).
 - Tri-phase unbalance load flow (this stage was covered developing algorithm and testing in MATLAB).

2.2. Project *SimSP*

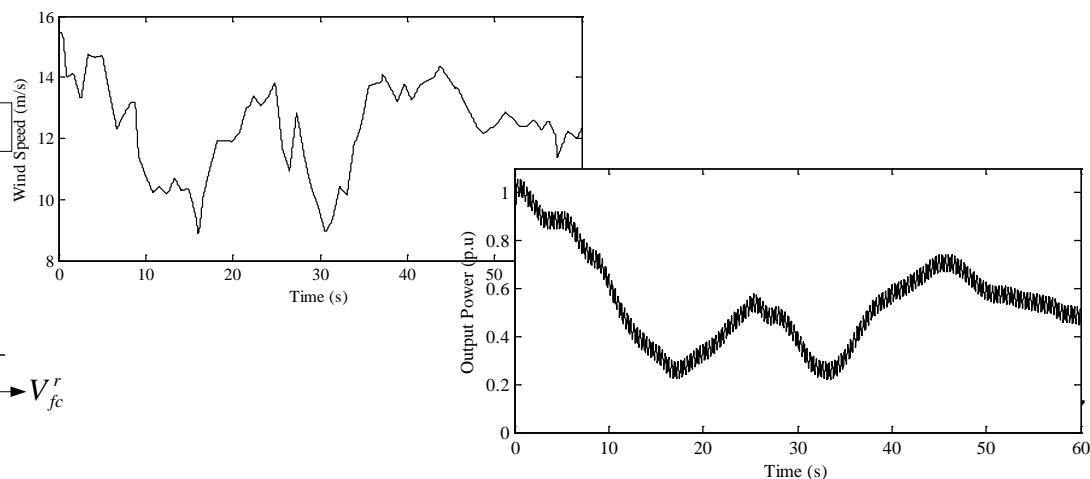
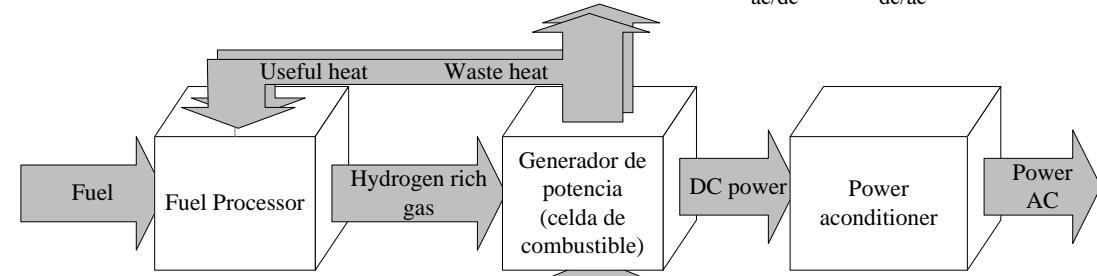
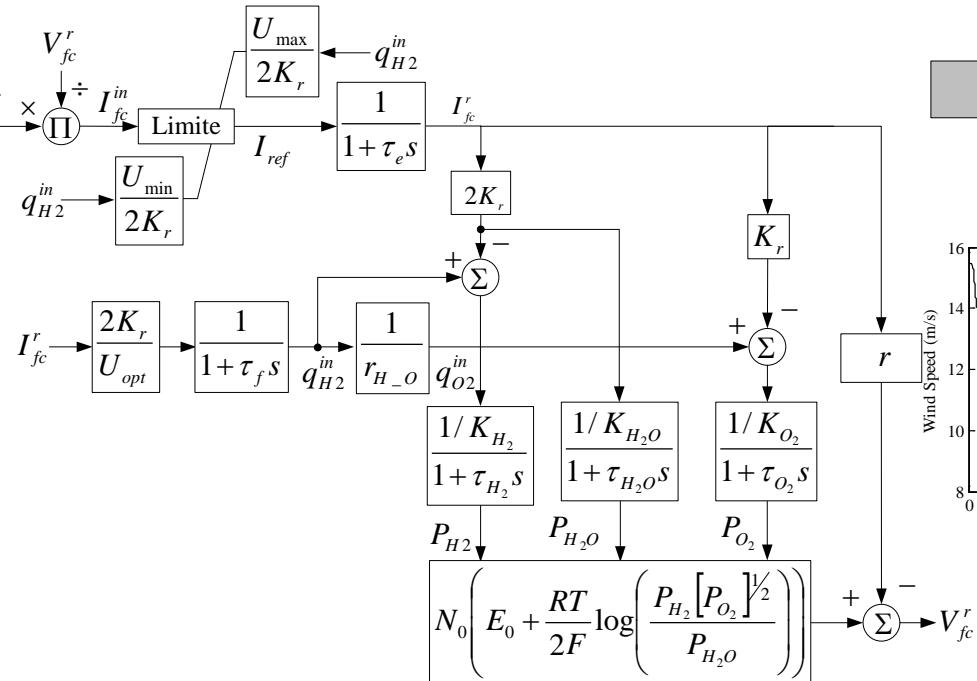
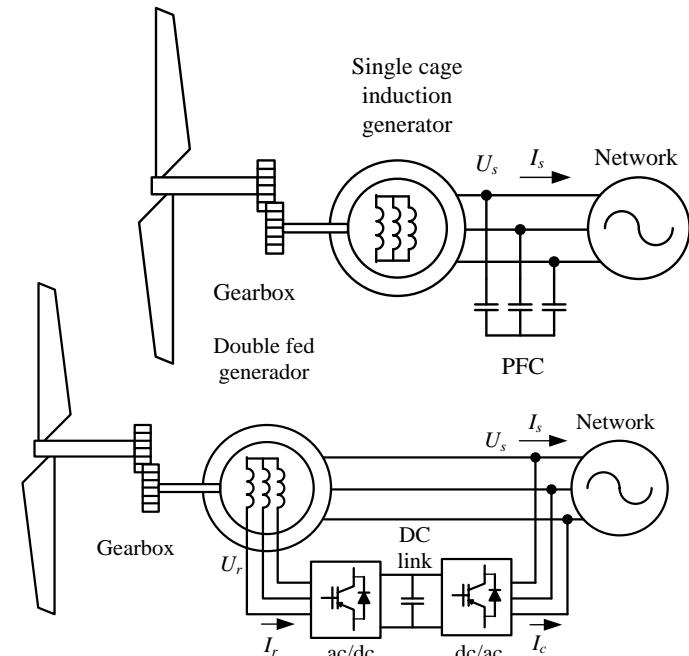
2.2. Project SimSP

- Abbreviation of **Power System Simulator** in Spanish **Simulador de Sistemas de Potencia**.
- SimSP is a complete program for power system analysis with **research purposes**.
- The main issue is include **new form of generation and renewable energy resources**.
- High **flexibility** for integration: data and procedures.
- **Block oriented programming based in state vector**.



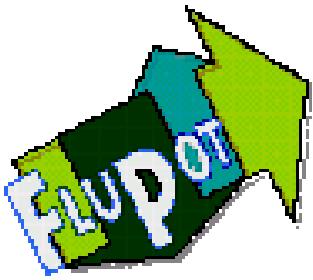
2.2. Project SimSP

- Include models of:
 - All traditional devices.
 - Wind turbines (Constant speed and Variable speed)
 - Fuel Cells (SOFC y PEMFC)
 - Micro turbines (Simple shaft and Split shaft)



2.2. Project *SimSP*

- Derived software:



Load flow in power system including wind turbines and wind farms



This program provide several operating point of the induction machine (motor and generator operation mode).



Load flow in distribution system with distributed generation

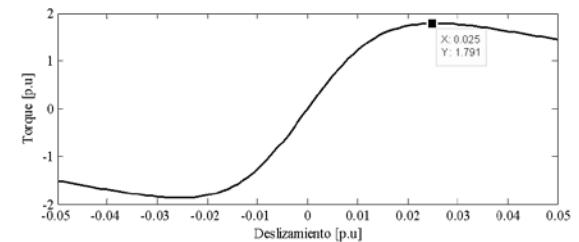
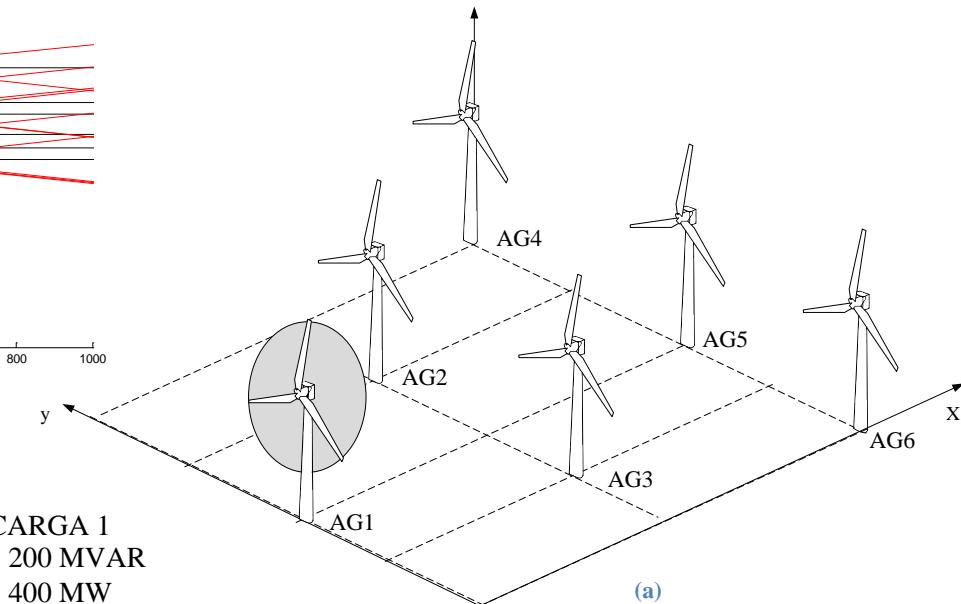
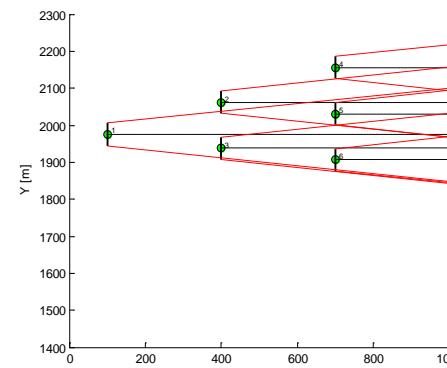
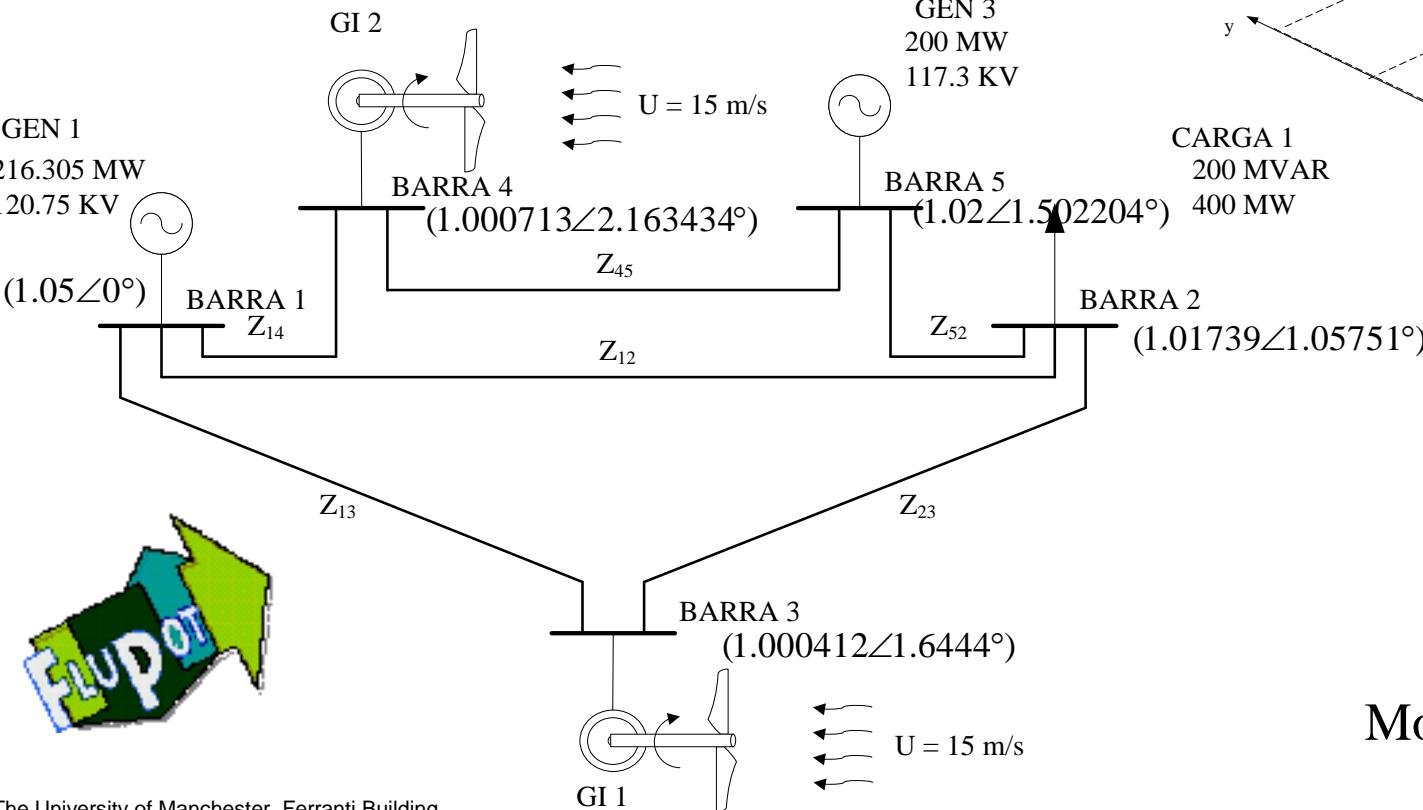
OPTGDI

Optimal allocation of distributed generation

2.2. Project SimSP

- Load flow in power system including wind turbines and wind farms

Wake model inside wind farm



Model of Induction Machines

2.2. Project SimSP

- Load flow in power system with optimal allocation of embedded generation.

OPTGD

Objective function:

$$J = \sum_{i=1}^N P_{GD_i} (\text{MW})$$

where P_{GD_i} is the GD capacity at the i^{th} bus.

A. Thermal Constraint:

$$I_i \leq I_i^{\text{nomin al}}$$

B. Equipment Ratings

1) Transformer Capacity:

2) SCL: A maximum short circuit rating

$$SCL_{TX} \triangleleft SCL_{\text{nomin al}}$$

$$\sum_{j=1}^N \delta_{jTX} P_{GD_j} + \alpha_{TX} \leq SCL_{\text{nomin al}} (\text{kA})$$

C. SCR

$$SCL_i = \alpha_i + \sum_{j=1}^N \delta_{ji} \times P_{GD_j}; i \neq j \quad \forall N$$

D. Voltage Rise Effect

$$V_{\min i} \leq V_i \leq V_{\max i}, \forall N$$

$$\mu_i P_{GD_i} + \beta_i + \sum_{j=1}^N \mu_{ji} P_{GD_i} \leq V_{\max i} \quad i \neq j$$

E. Energy Resource and Customer Initiatives Constraint

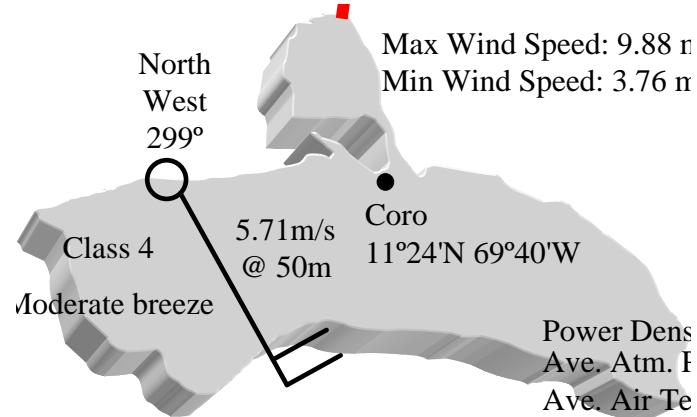
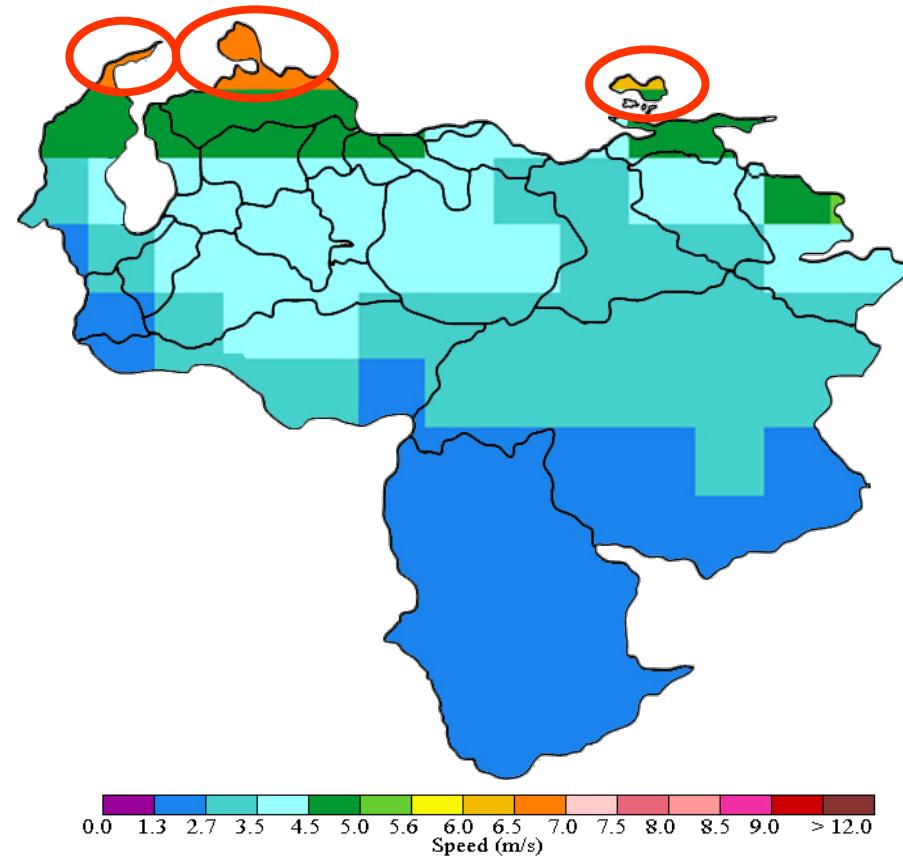
$$P_{inst_i} \leq P_{GD_i} \leq P_{avail_i}, \forall N$$

3. Wind Energy

3.1. Resource Assessment and Project Evaluations

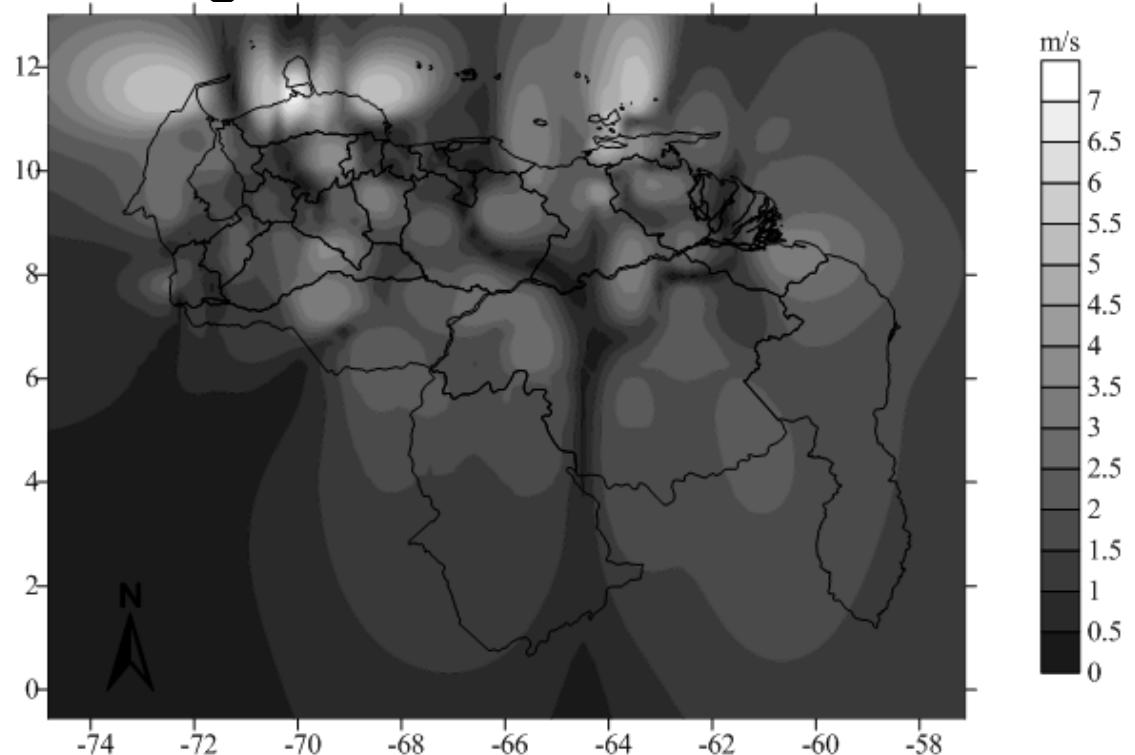
3.1. Resource Assessment and Project Evaluations

- Wind Energy assessment using satellite and macro-variable data.
 - Statistic model for wind data analysis: Wind rose, Histogram.
 - Probabilistic model for wind data analysis: Weibull and Rayleigh distribution.
- Preliminary wind energy evaluation of wind farms: RETScreen, WindPro, etc.



3.1. Resource Assessment and Project Evaluations

- Wind Energy assessment using local measurements.
 - Complete data missing
 - Correlation analysis
 - Stational correction
 - Spatial interpolation:
 - Wind speed
 - Wind direction



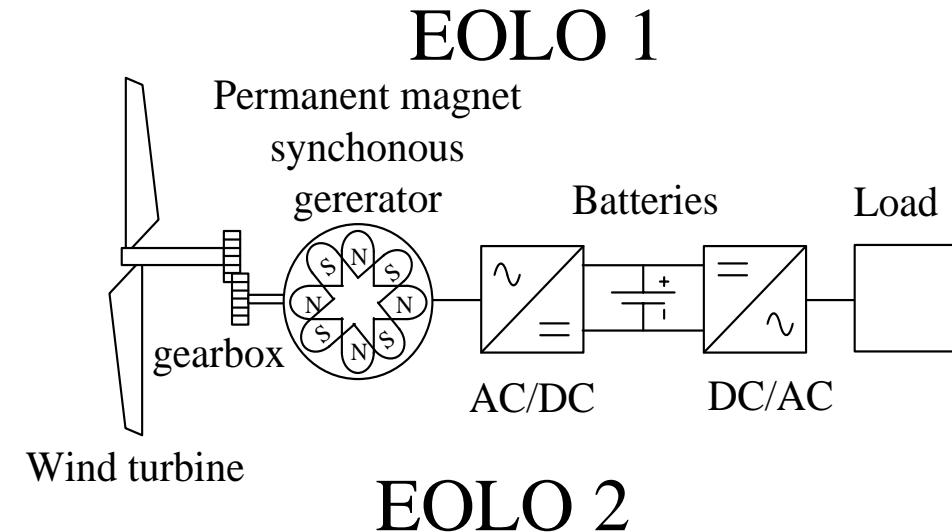
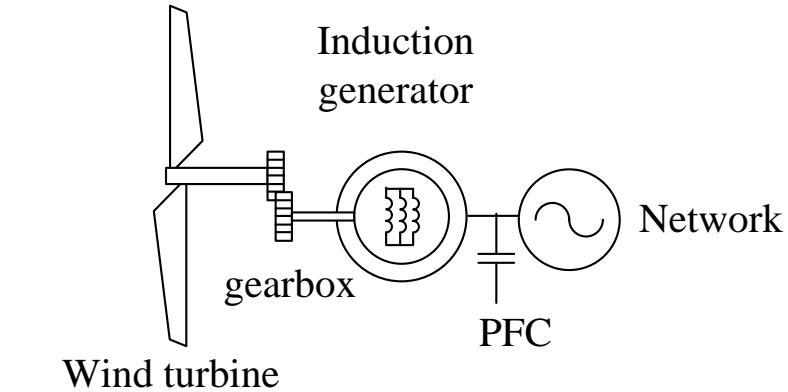
$$u_{kc} = \left(1 + \frac{h_{k-1}^{LAT} + h_{k+1}^{LAT} - 2h_k^{LAT}}{2\Delta x} \right) u_k + \frac{h_k^{LAT} - h_{k+1}^{LAT}}{2\Delta x} u_{k+1} + \frac{h_k^{LAT} - h_{k-1}^{LAT}}{2\Delta x} u_{k-1}$$

$$v_{kc} = \left(1 + \frac{h_{k-1}^{LON} + h_{k+1}^{LON} - 2h_k^{LON}}{2\Delta y} \right) v_k + \frac{h_k^{LON} - h_{k+1}^{LON}}{2\Delta y} v_{k+1} + \frac{h_k^{LON} - h_{k-1}^{LON}}{2\Delta y} v_{k-1}$$

3.2. Development of Prototypes

3.2. Development of Prototypes

- Project EOLO
- To develop of the first Venezuelan prototype of small wind turbine:
 - Wind energy resources assessment
 - Design of the turbine rotor blades
 - Design of the drive train
 - Lab test of the generator (180W)
 - Design of the support
 - Simulation of the behaviour.



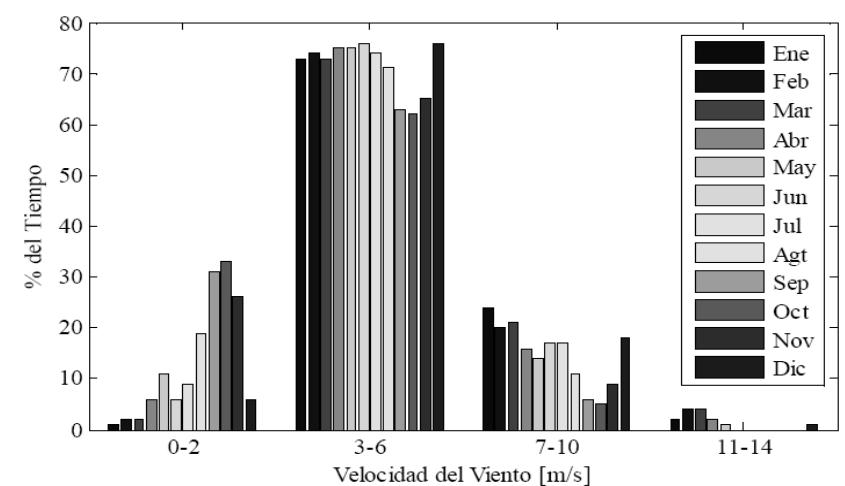
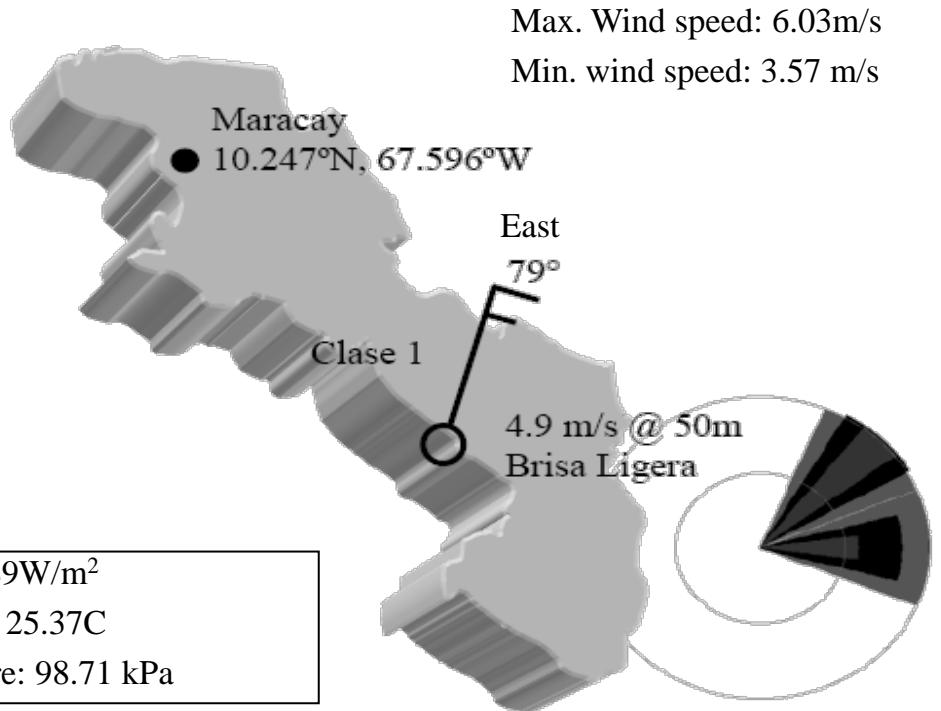
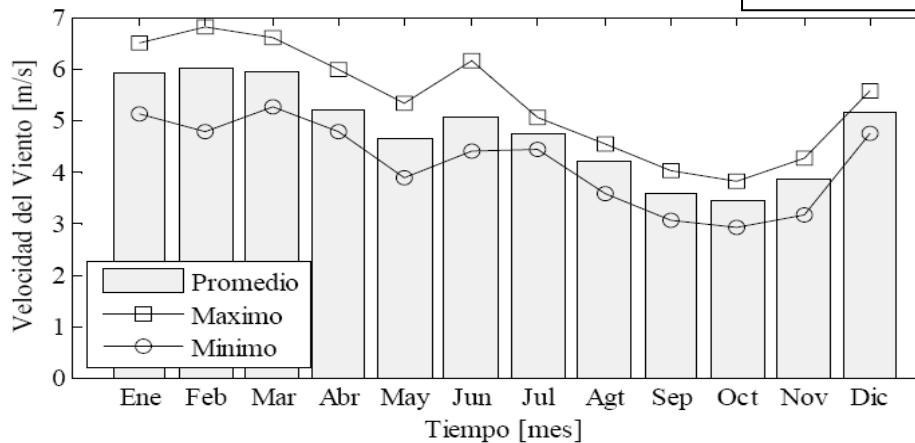
STAGE 1: Wind energy resource assessment



STAGE 1: Wind energy resource assessment

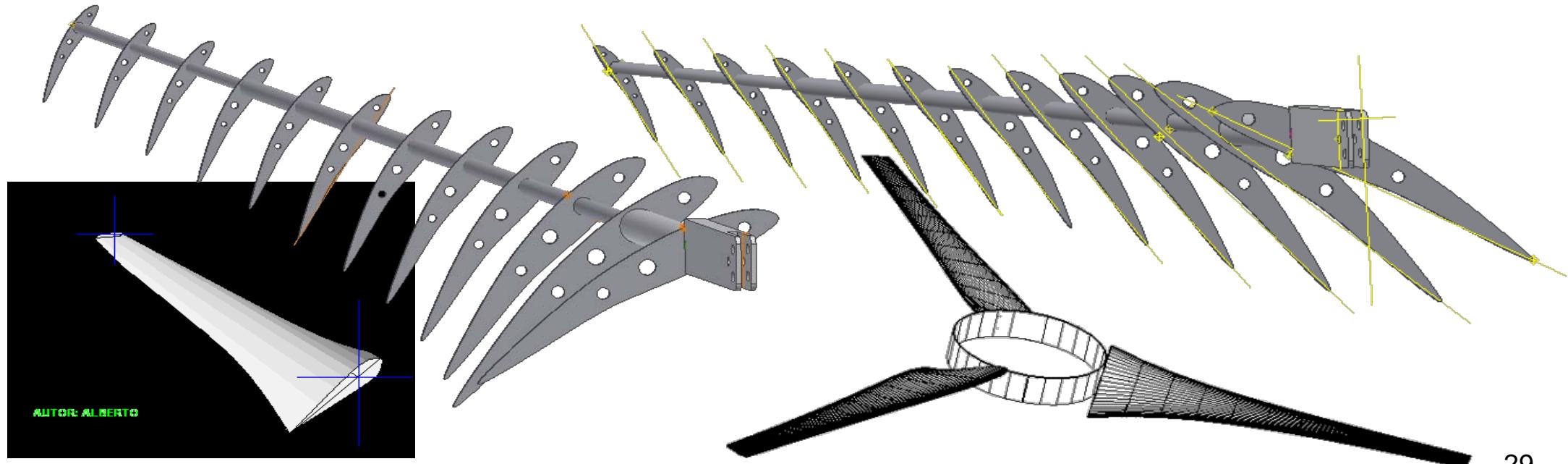
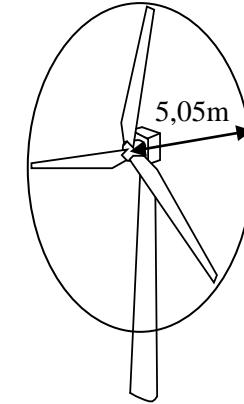


Av. Power density: 89W/m²
 Av. Air temperature: 25.37C
 Atmospheric pressure: 98.71 kPa



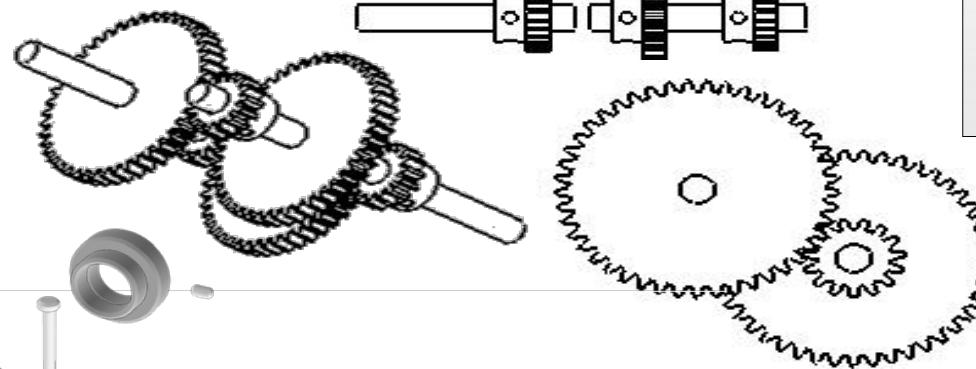
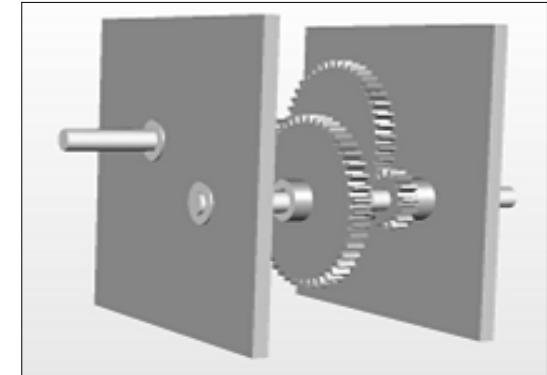
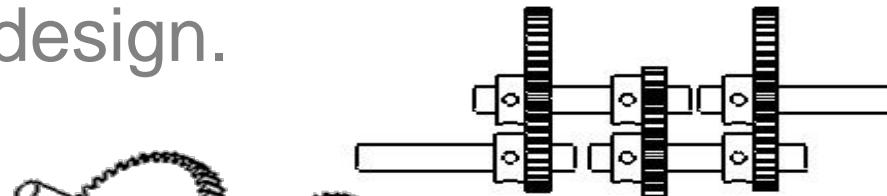
STAGE 2: Design of the turbine blades

- Constant speed wind turbine
- Stall regulated
- Airfoil Wortmann FX 60-126

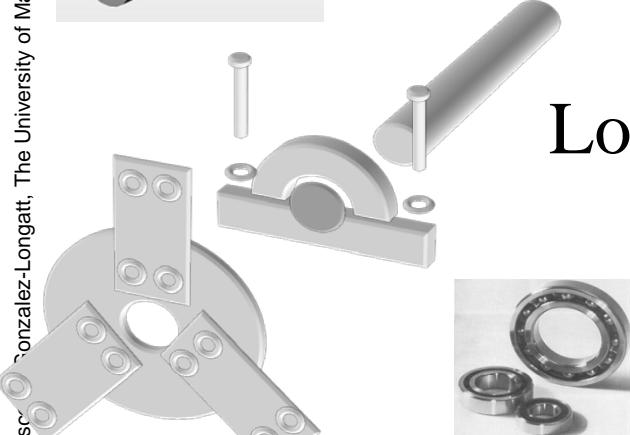
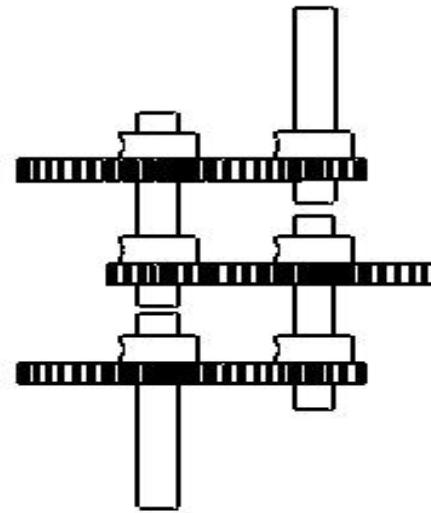


STAGE 3: Design of the drive train

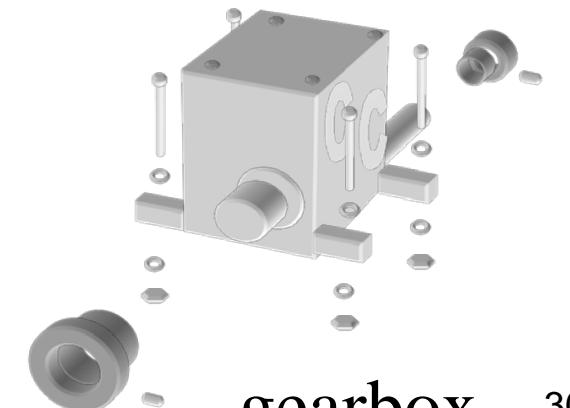
- Gearbox based in Straight-cut gears.
- Parallel axis design.
- 3 Stages



Low Speed shaft



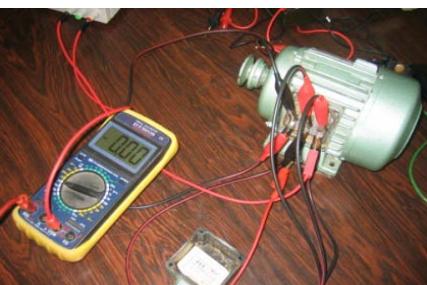
Hub



gearbox

STAGE 4: Lab test of generator

- Single squirrel cage induction generator
- 180 Watt
- Test carried out in UNEFA laboratory

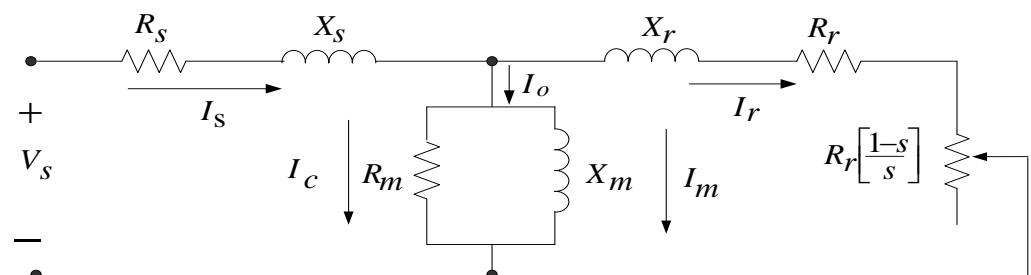
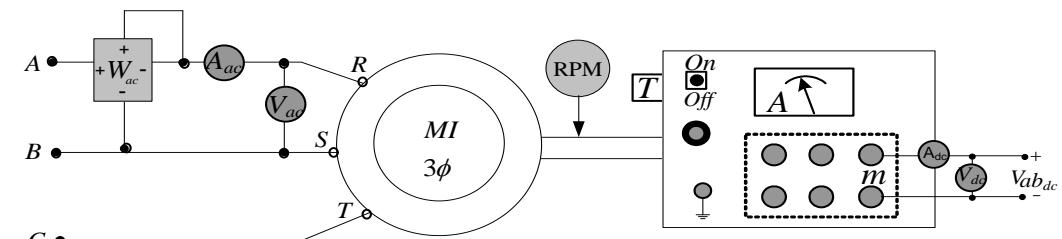
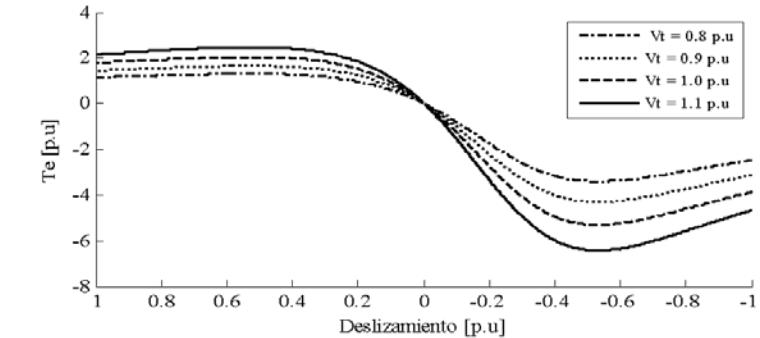
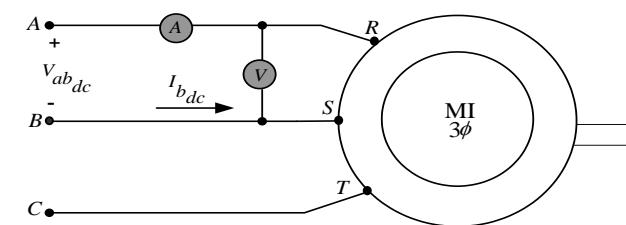
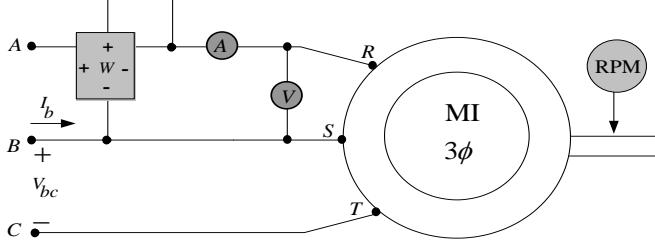


ELECTRICAL
ENGINEERING
DEPARTMENT
UNEFA-Maracay



STAGE 4: Lab test of generator

- Later a large induction generator was tested
- 746 Watt



STAGE 5: Design of the tower



Guyed small cylindrical Towers

Project EOLO-1
10°12'21.09"N
67°38'26.89"O



No climbable for inspections or repairs

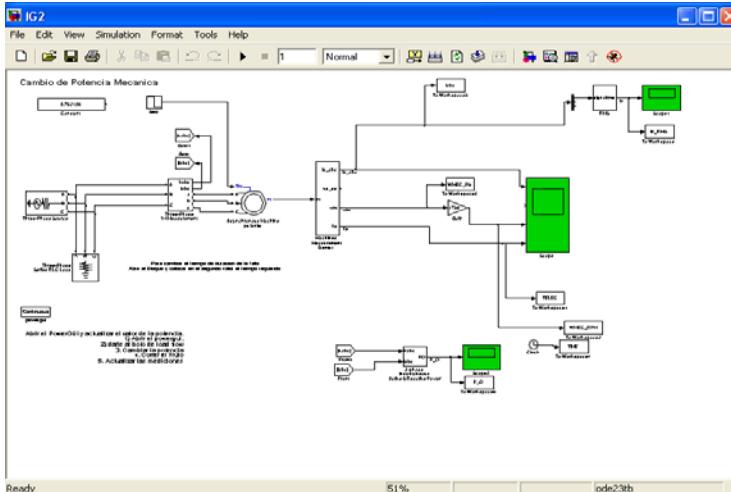
Flexible tower



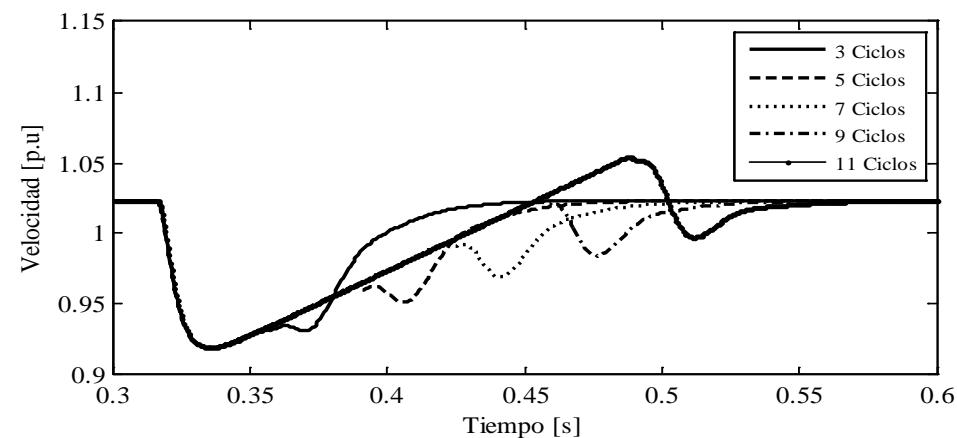
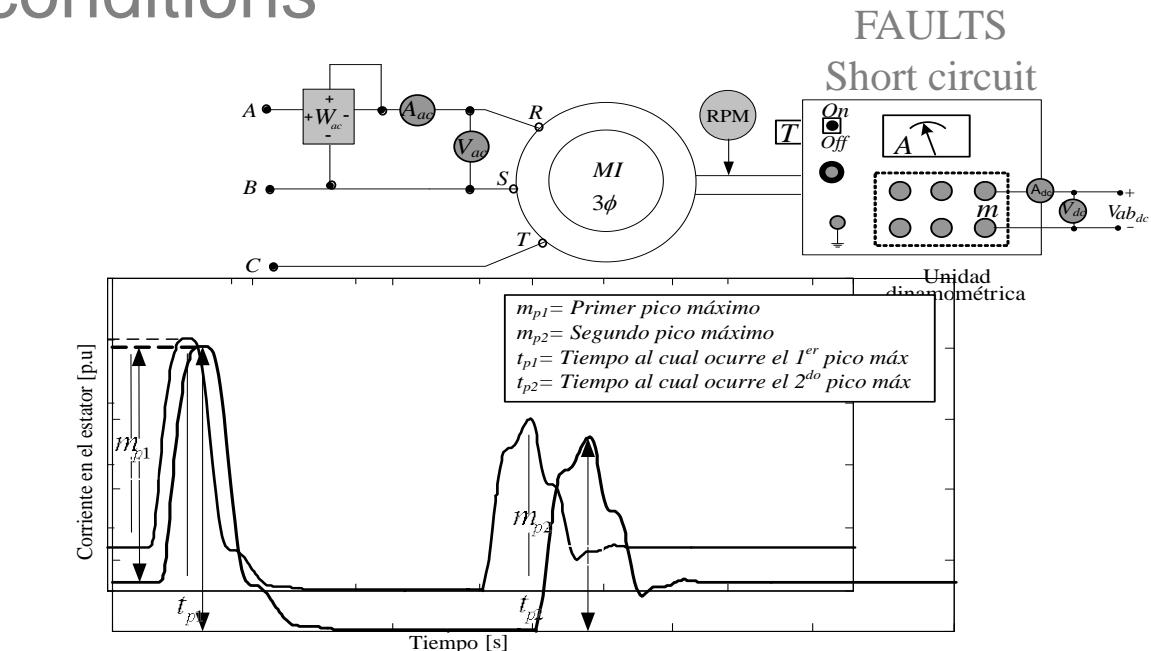
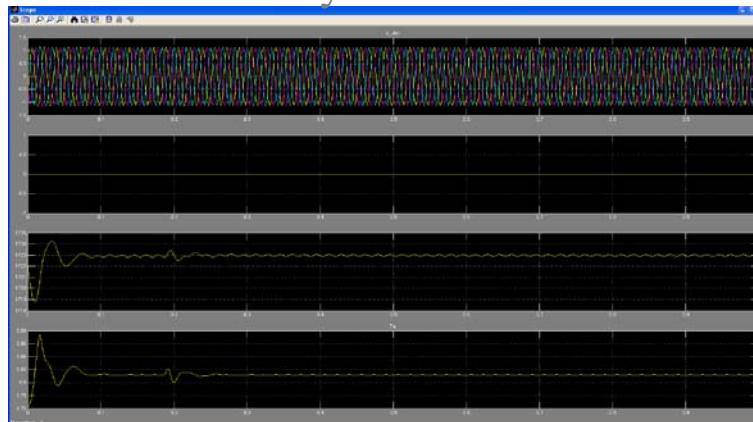
STAGE 6: Simulation of the behavior

- Simulate the operative conditions

Steady State



Dynamic



3.2. Results

- **Ten (10) undergraduate projects** of: Electrical, Mechanical and Aeronautic engineers.
- **Fourteen (14) papers published in events.**
- **Eight (8) tutorial** dictated by Prof. Francisco Gonzalez-Longatt



Thank you!

Any questions?