Technical Constraints on RES Penetration Imposed by Electrical System Operation and relative Software Evaluation Tools

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Background

- Need for calculations regarding RES penetration limits
- Penetration limits can be related to electricity generation or transmission
- Reliability and Security issues may impose limits to RES penetration if they have as a consequence high electricity prices or if investments required cannot be implemented in the desired time framework

Background

- Software tools are required for such calculations towards an integrated resource planning

RES penetration limits

Parameters affecting the system expansion :

- Storage capacity requirement to balance the energy curtailment due to non-dispatchable renewables which are producing when the load is small
- Reserve capacity requirement due to hourly variations of the equivalent load
- Transmission grid expansions related to the penetration of high RES potential areas

RES penetration limits

Parameters affecting the grid operation are:

- External interconnections
- Topology of power grid
- Distribution of RES plants
- Electrical and Control Systems of RES plants
  - Low Voltage Ride Through (LVRT) capability in Wind Turbines
  - Contribution of RES to frequency and voltage control

Calculations required for implementing plans of a wide-scale penetration of RES

Taking into consideration environmental and energy policy constraints it is necessary to calculate :

- Least cost electricity generation technologies mix to meet the energy demand
- Generation from both dispatchable and non dispatchable plants
- Electrical energy consumption per sector

Calculations required for implementing plans of a wide-scale penetration of RES

- Residual Load Duration Curves analysis for analyzing weekly, monthly or yearly load curves to define storage and peak load units size
- Reliability analysis calculating the reserve required for hourly variations of the Residual Load
- Probabilistic Production Costing with detailed analysis of the operation of the generation system to calculate the cost of electricity

Calculations required for implementing plans of a wide-scale penetration of RES

Static security assessment

- Evaluation of different static scenarios
  - Normal (N)
  - Emergency conditions (N-1) or (N-2)

Defines problems related to

- Congestion on transmission lines
- Geographical distribution of plants
- Bus Voltage
- Needs for network reinforcements

Calculations required for implementing plans of a wide-scale penetration of RES

Dynamic security assessment

- Evaluation of a power system's response to disturbances such as
  - Variations of load and electricity production and short circuits in transmission system

Define problems related to

- the ability of a power system to remain stable after a major disturbance

Calculations required for implementing plans of a wide-scale penetration of RES

In particular to identify the ***critical operating conditions*** under high level of wind power penetration:

- Static Security Issues:
  - **Violation of *"N"* Criterion** (voltages 5% above or below nominal levels, power flows greater than circuit ratings).
  - **Violation of *"N-1"*, *"N-2"* Criteria** (voltages 10% above or below nominal levels, power flows greater than circuit ratings).

Calculations required for implementing plans of a wide-scale penetration of RES

- Dynamic Security Issues:
  - **Significant loss of wind generation** due to the operation of under/over-frequency and voltage relays when severe contingencies occur.
    - Hellenic interconnected power system case: Loss of wind generation that is greater than 600 MW.

Software Tools-Expansion Planning

- TIMES MODEL and

Incorporating in TIMES additional costs related to wide scale RES penetration such as :

- Storage capacity required to balance the energy curtailment due to non-dispatchable renewables which are producing when the load is small
- Reserve capacity required due to hourly variations of the equivalent load

Software Tools-Expansion Planning

- Reserve capacity required related to peak load demand
- Integration of grid expansion calculations of TIMES (DC Load Flow-grid expansion cost functions)

  with KANORS-EMR

Software Tools-Electricity Cost

COST-P model for Probabilistic Generation Analysis and Costing :

Two plant categories are considered :

- Dispatchable (Thermal, Dam Type Hydro, Pumped Storage)
- Non-dispatchable (Wind, PV, Run off River(small hydro), small CHP)

It combines customer load statistics with non dispatchable generation statistics

Software Tools-Electricity Cost

- Using the technology mix of TIMES as an input in COST-P model we obtain an accurate calculation of the electricity generation cost

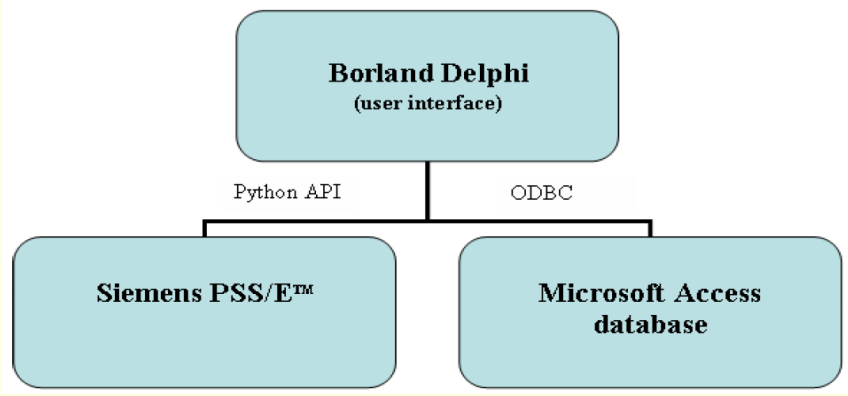
COST-P is operating on a weekly basis and is using RLDCs which are formulated from the convolution of the customer load forecast (hourly values) with the non dispatchable generation forecast (also hourly values)

Software Tools-Grid Operation

- Unit Commitment Module (configuration of power generation scheme)
- Static Security Analysis Module (Load-flow problem)
- Dynamic Security Analysis Module (System response to disturbances)

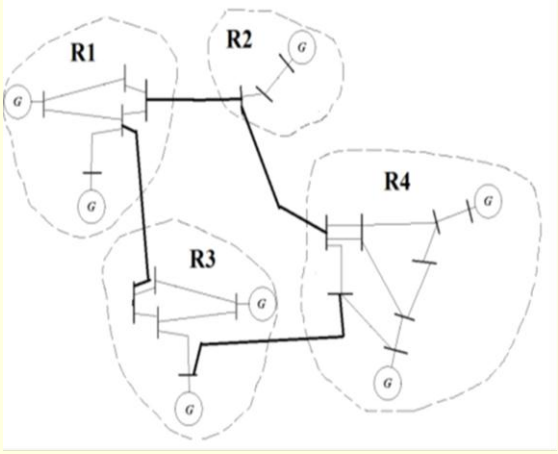
Development under the PSS/E environment

Software Tools-Grid Operation



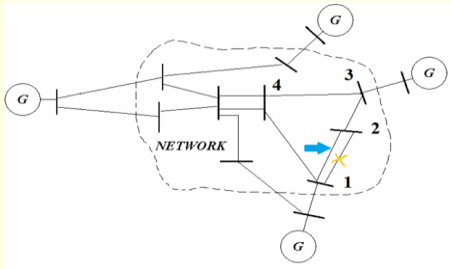
Integration

- Grid calculations in regional TIMES (DC load flow)



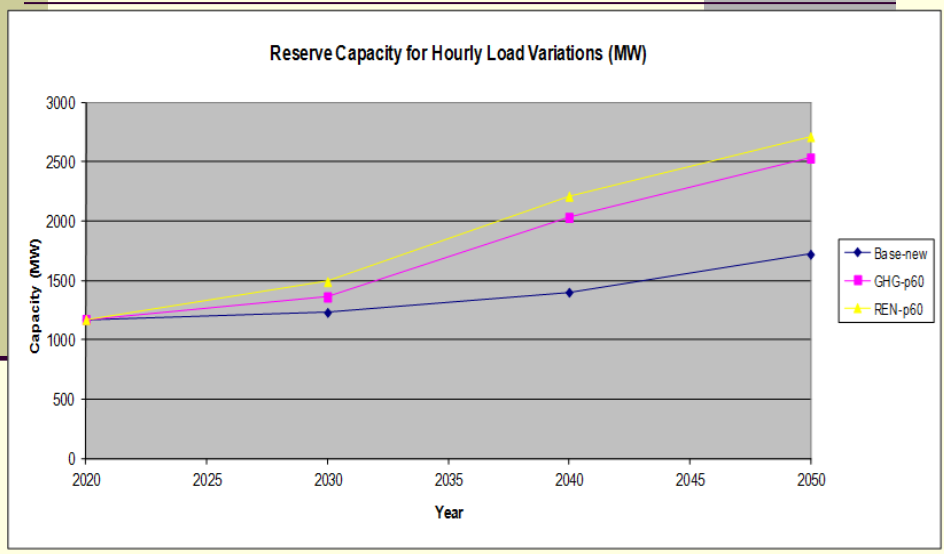
Integration

- Grid related cost functions in TIMES



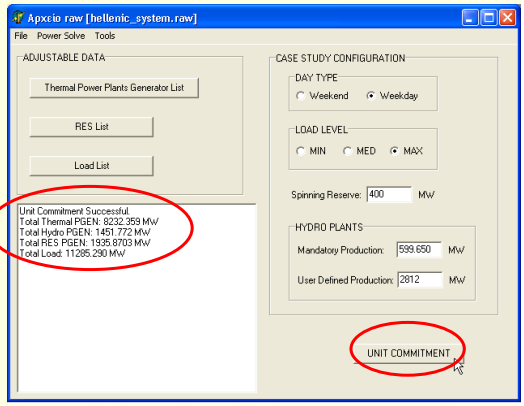
$$C_I(P_{Gi}, P_{Li}) = C_{I0} + A_{I1}\left(P_{Gi} - P_{Gi}^0\right) + A_{I2} \cdot \left(P_{Li} - P_{Li}^0\right)$$

Reliability Module - Results



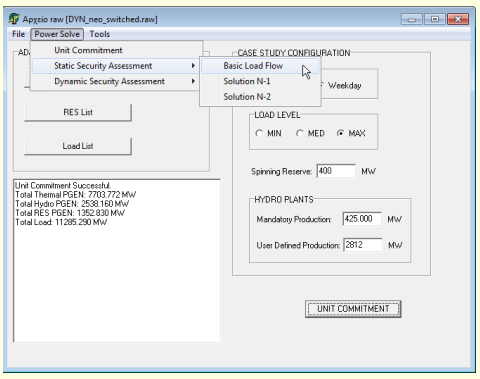
Grid Module-Unit Commitment

- First step → Unit Commitment
  - Fossil-fuel units (min. output level)
  - Hydroelectric plants (mandatory generation)
  - RES units (except WFs)
  - Combined Cycle units (min. output level)
  - WFs (user defined)
- Second step → Loading of units
  - Fossil-fuel units (up to 95%)
  - Combined cycle units (up to 95%)
  - Hydro plants (up to 80%)
  - Gas Turbines (up to 95%)
- Termination of the algorithm
  - Successful
  - Not Successful → - Insufficient generation - Violation of technical restrictions for thermal plants



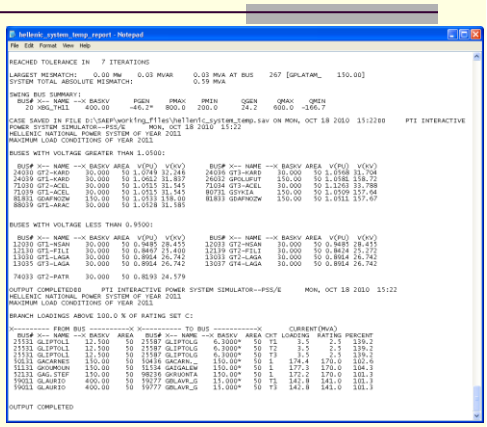
Grid Module-Static Security Assessment

- Load flow formulation ready from previous steps:
  - Case topology launched initially by user
  - Loads defined by user
  - Generation scheme defined by the previous module



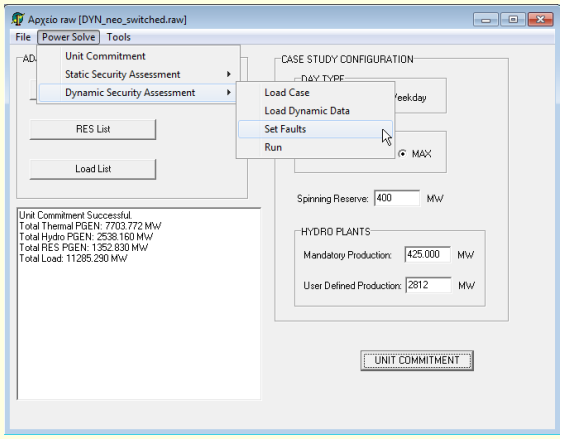
Grid Module-Static Security Assessment

- Load flow solution
  - "N" – Normal topology
  - All "N-1" contingencies
  - Critical "N-2" contingencies
- Data report with results/messages



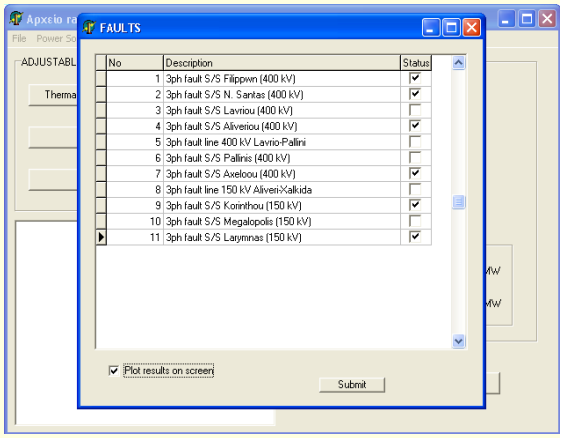
Grid Module-Dynamic Security Assessment

- Initial conditions defined by load flow results.
- Use of files of load flow results (.sav) and dynamic data (.dyr).



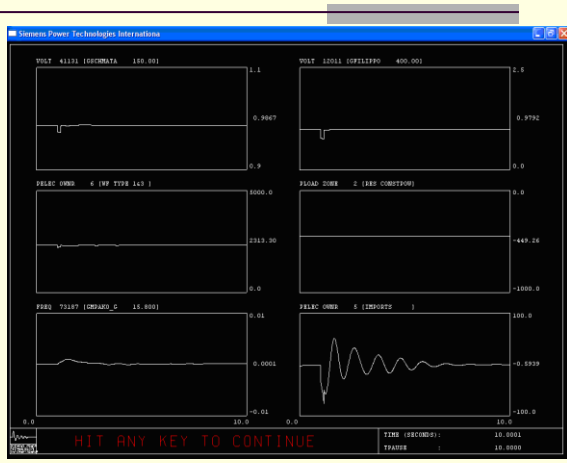
Grid Module-Dynamic Security Assessment

- Select faults to be simulated
  - Hellenic power system case: 3-phase faults



Grid Module-Dynamic Security Assessment

- Run and obtain results in a graphical way.



Production Costing Module