An Improved Version of the Model JUANAC: Applications to Network Adequacy and Economic Studies in Large Interconnected Power Systems

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Summary

JUANAC is a computer model that can be used to perform production cost and transmission adequacy studies of bulk electric power systems consisting of either one o multiple areas (i.e., independently but coordinated dispatched systems), both under traditional and competitive regulatory frameworks.

The version of JUANAC presented in this paper includes significant improvements over the initial model [6], in particular the capability of simulating any number of user specified scenarios representing a full year operation, modelling different types of third party access (TPA) contracts, simplified unit commitment and weekly hydro dispatch capabilities, and the optional use of preventive security criteria for system dispatch.

These features allow JUANAC to be useful in different types of studies of network adequacy and economic evaluation of transmission services under various regulatory environments, particularly with competitive schemes that significantly increase the uncertainty normally encountered in the activities of designing and operating the transmission network. One representative case is the widespread attention given to third party access in many utilities throughout the world; JUANAC may be used as an aid to determine transit fees, to evaluate whether a proposed TPA transaction should be authorised or not, or to assess the impact of TPA transactions on the adequacy of the network; JUANAC can model TPA transactions that take place between agents located within a single area or in different areas. Another example is the precise evaluation of the impact of preventive security dispatch (as compared to ordinary economic dispatch with prescribed security margins on the level of network utilisation) on the remuneration of transmission services based on marginal prices.

JUANAC can typically be used to analyse one year of the system operation:

- The *year* is decomposed into as many seasons and load levels as the user specifies.

  The following parameters are allowed to take different values for each season and load level: area exchanges; load and unserved energy cost for each bus; minimum, maximum and scheduled hydro power generation and the cost associated to the use of emergency hydro power; minimum and maximum capacity of each thermal unit and its associated linear and quadratic heat rates; maximum line power flow capacities.

- Each *season* is decomposed into as many periods as the user specifies.

  This division allows to take into account unit and line maintenance plans. The user assigns to each period a duration and the units and lines under maintenance. The sum of the duration of all the periods belonging to the same season determines the duration of this season.

- Each *period* is analysed for each of the *load levels* defined.

  The weight assigned to each load level within each period is defined by the user. According to these weights, the load levels within each period have an associated duration.

- Finally, for each load level within each period, as many *system failure states* as the user specifies are analysed.

  The user determines each system failure state as a list of elements (generation unit, line)

failed. A probability given by the user determines the relative weight of each system failure state.

Summarising, a scenario corresponds to a given load level, a given period (with the corresponding maintenance plan and season assigned), and a given system failure state. For each scenario a power dispatch is determined by JUANAC and the results are translated into energy and monetary units according to its calculated duration and probability.

The main characteristics of the current model are:

- Unit commitment of thermal units for each period determined heuristically. It is needed when the units have to be disconnected from the network because shutdown at night is not possible. It takes into account the relationship among the different load levels of a period.
- Heat rate of a thermal unit can have a linear and quadratic term. The second term has not been found in any other model.
- Hydro energy management into the period to balance the hydro energy production among the different load levels.
- Flows through the network are modelled by the so called DC approximation, extended to consider ohmic losses.
- Losses are represented as a nonlinear approximation and included directly into the constraints of the optimisation problem. This representation of losses is more robust than the iterative procedure used in other related models (for example, ESCORT [2]).
- Either a N-1 preventive security dispatch for the network or just a security coefficient for each line is implemented to take into account the network contingencies.
- Although a central economic dispatch is formulated, interchanges among areas are allowed. Their values are predetermined by the user or left free.
- Results are aggregated by areas and companies.

The optimal operation of the generation and transmission system is formulated as an optimisation problem with nonlinear objective function if the quadratic heat rate term is considered and with nonlinear constraints if losses are included. The problem is solved using the general purpose nonlinear optimisation package MINOS [5].

JUANAC obtains all the classical results of an operations planning model (total operation cost, units generation and cost, line power flows and ohmic losses, unserved energy, ...), and results related to marginalist theory (spot prices, network revenues, unit revenues, ...). Both power and energy related results are obtained.

The model has been fully tested and applied extensively to real large-scale power systems. The potential applications include:

- Determination of yearly spot prices map for several large systems as the Spanish (600 nodes and 700 lines), the Chilean (300 nodes and 400 lines) and the Argentinean (reduced to 20 nodes and 30 lines) power systems. The spot prices are then used either as useful sensitivities for example for long term transmission expansion planning [1] or as real economic values for the current cost based market in Argentina.
- Study of marginalist tariffs of the services provided by the transmission network in the Spanish power system [7].
- Economic assessment of pumped storage operation in the South African power system [3].
- The evaluation and pricing of interchanges among Central American (250 nodes and 325 lines) countries taking the Central American power system as a whole [4].
- Evaluation of the transmission network costs and revenues under marginal premises in the Chilean power system.

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