Critical Importance and Role of Power Generation Planning in the Power System

By

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Training Workshop

"Identification, Comparison and Scenario Based Application of Power Demand/Load Forecasting Tools"

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About Power Planners International

- Power Planners International is a limited company in Pakistan and in England and Wales and in Saudi Electricity Company (SEC)
- PPI has its footprints in SAARC Region:
  - Nepal: Consultant on 400 kV Trunk Line for US Donor MCC
  - Sri Lanka Consultant for CEB for planned SVC in Colombo
  - Afghanistan: Consultant for GIZ to improve Energy Security and Power System Enhancement
- PPI possess the technical skills to perform for a grid system of any size, the following:
  - Feasibility Studies of integration of power plants with the main grid.
  - Load flow, optimal power flow, and short circuit analysis.
  - Dynamic and transient stability analysis for all kinds of disturbances in the system

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- Voltage stability, voltage control, and voltage collapse analysis and remedies by compensating devices like shunt capacitors/reactors banks, SVCs, FACTS, Series Compensators, STATCOMs, etc.
- Small signal stability analysis and remedies by power system stabilizers (PSS) in the system
- Engineering, design and specifications of substations, overhead lines, cables and FACTS devices
- Load forecast analysis based on historical data, power market surveys, economic growth indices like GDP or GNP, population growth rates etc. using econometric models, time-series models, end-users models etc
- Optimized Generation Planning
- Analysis of transfer limits of Cross-Border Interties

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Agenda of the Presentation

- Load Forecast: Very Important/Critical input for Generation Planning
- Classical Generation Planning for State Owned Monopolized/Centralized Power Sector
- Modern Generation Planning for Present Power Sector:
  - Private-Public Mix
  - Private Market
- Role of Renewables in Generation Planning
- Role of Cross Border Power Trading in Generation Planning
- Conclusions

Load Forecast: Very Important/Critical input for Generation Planning

- **Global or Temporal Forecast (for Generation Planning)**
  - Entire Power Sector as one bus
  - Country-wide
    - Economic Growth indices e.g. GDP, GNP etc
    - Population Growth
    - Sector-wise Growth i.e. Domestic, Commercial, Industrial, Agricultural etc.
- **Spatial Forecast (for Transmission/Distribution Planning)**
  - Area-wise or Region-wise Growth
  - Growth at levels of City, Towns, Cluster of villages
  - New Housings, New Industries or Commercial Complexes, Defense or Strategic Developments

Classical Vs Modern Models of Generation Planning

- Classical Generation Planning Model:
  - For State Owned Monopolized/Centralized Power Sector
- Modern Model is for Open Market Economies
- Technical Parameters are same for both
- Economic, Financial and Commercial Parameters are different for both
- Renewables are Vital Part of Modern Model

Parameters of Least Cost Generation Plan

- Economically optimal expansion policy of an electric utility
- Supply-side & demand-side resources
- Probabilistic estimation of system production costs:
  - Avoided costs
  - Marginal costs
  - Incremental costs
  - O & M Costs (including Fuel costs)
  - Capacity costs
- Unserved energy costs
- Reliability (LOLP/LOLE)
- Fuel availability
- Constraints on environmental emissions

Techniques and Software

- **Techniques:**
  - Dynamic programming method for optimizing the costs of alternative system expansion policies meeting reliability constraints
  - Linear programming technique for determining optimal dispatched policy satisfying exogenous constraints on environmental emissions
- **Software**
  - WASP (Version-IV) by IAEA
  - EGEAS (Version 11) by EPRI
  - SYPRO

Technical Data of Existing and Proposed Generating Units

- Common to Hydel, Thermal and Nuclear
  - Installed capacity (MW)
  - Unit spinning reserve as % of MWC
  - Unit forced outage rate (%) i.e. FOR
  - Number of days per year required for scheduled maintenance of each unit
  - Maintenance class size (MW)
- Hydel Plant:
  - Type (Reservoir, Run of River or pump storage)
  - Hydro Conditions and Energy Available in each condition
  - Probability of hydro-conditions
  - Minimum and Maximum operating Levels
  - Energy storage capacity (GWh).

Technical Data of Existing and Proposed Generating Units

- Thermal & Nuclear Plant
  - Type: Steam, Combined Cycle or Open Cycle
  - Thermal Fuel Type: Oil (Crude, RFO, HFO, Diesel), Coal, Gas etc.
  - Minimum and Maximum operating Levels
  - Heat rate at minimum/maximum operating level (kcal/kWh)
  - Average incremental heat rate between minimum and maximum operating levels (kcal/kWh)
  - Polluting Emission rates and specific energy use

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Cost Data of Existing and Proposed Generating Units

- Common
  - Capital investment costs
  - Salvage value of investment costs
  - Fixed/Variable component of non-fuel operation and maintenance cost ($/kW-month) of each unit; it is assumed to be a domestic cost
  - Cost of the energy not served
  - Plant Life
- Thermal:
  - Domestic fuel costs
  - Foreign fuel costs
  - Fuel inventory costs

Generation Planning Reliability Criteria

➢ Deterministic Approach

- Reserve Margins consisting
  - Hot Active Spinning Reserve (ASR) for unscheduled outages
  - Maintenance Reserves for scheduled outages
  - Planning Reserves to address uncertainties in demand forecasts
- Total Reserves Margin from 10-15 % of Planned Generation

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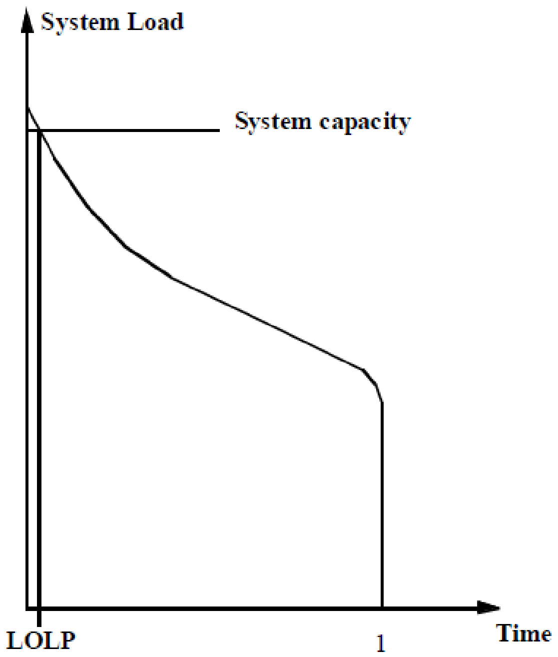
Generation Planning Reliability Criteria

➢ Probabilistic Approach

- **Loss of Load Probability (LOLP) or Loss of Load Expectancy (LOLE)**
- It is defined as the probability (fraction of time) that the system demand is not fully satisfied, or in other words, that the system demand exceeds the available capacity
- Usually 0.2 days/year (4.8 hrs./year.
- (0.1 to 0.6 is an acceptable range)



Generation Planning Reliability Criteria

- **Expected Energy Not Served (EENS)**
  - Unserved energy, expressed in GWH,
  - It is calculated using operating capacities
  - It represents the portion of the initial system energy expected not to be met by the system's generating units.
  - If desired, you can assign a cost to this energy in terms of dollars per MWH.

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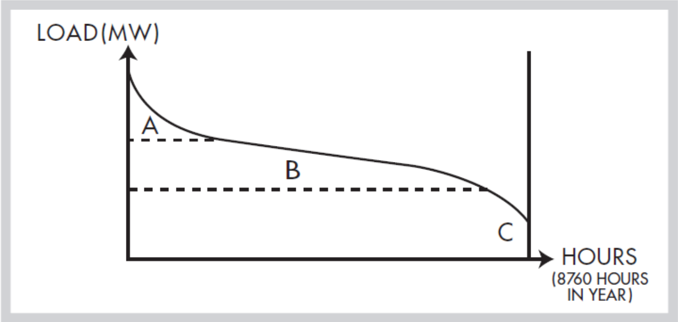
WASP : A Model of Generation Planning

➢ Input Modules:

- **Load Forecast: LOADSY**
  - Processes information describing
    - period peak loads
    - load duration curves (LDC) for the power system over the study period
  - For Example for a 30 years' Plan Period, we will feed 30 annual LDCs, and if we feed monthly LDCs, 360 curves will be fed

FIGURE E.1 Load duration curve.



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WASP : A Model of Generation Planning

- **FIXSYS (Fixed System Description)** :processes information describing the
- Existing generation system (hydel, thermal or else)
- Pre-determined additions of units(ongoing or firm planned)
- Pre-determined Retirements of units
- Information on any constraints imposed on
  - Thermal Units
    - Environmental emissions
    - Fuel availability
  - Electricity generation by some plants (Must Runs)
- All Technical and Costs Data of existing and pre-determined units

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WASP : A Model of Generation Planning

- **VARSYS (Variable System Description)** :processes information describing the
- Various generating plants which are to be considered as
  - Candidates for expanding the generation system e.g.
    - Number of candidate thermal plants of different types and different fuels
    - Number of candidate hydro projects
    - Number of Nuclear plants
- All Technical and Costs data of candidate plants same as in FIXSYS

WASP : A Model of Generation Planning

➢ Process/Analysis Modules

- **CONGEN (Configuration Generator)**,
- Develops and Calculates all possible year-to-year Combinations of Expansion Candidate additions (hydel, thermal, nuclear etc.) which satisfy certain input constraints and
- Which in combination with the fixed system can satisfy the loads.
- CONGEN also calculates the basic economic loading order of the combined list of FIXSYS and VARSYS plants.

WASP : A Model of Generation Planning

- **MERSIM (Merge and Simulate),**
- Considers all configurations put forward by CONGEN
- Uses probabilistic simulation of system operation to calculate the associated Production costs, energy not served and system reliability for each configuration.
- Limitations imposed on some groups of plants for their environmental emissions, fuel availability or electricity generation are also taken into account.

WASP : A Model of Generation Planning

- The dispatching of plants is determined in such a way that
  - plant availability,
  - maintenance requirement,
  - spinning reserved requirements and
  - all the group limitations

  are satisfied with minimum cost.
- The module makes use of all previously simulated configurations
- The analysis is done for whole plan period, say 30 years.

WASP : A Model of Generation Planning

- DYNPRO (Dynamic Programming Optimization)
  - Determines the
    - optimum expansion plan based on previously derived operating costs
  - Along with input information on
    - capital costs
    - energy not served cost
    - economic parameters
    - reliability criteria

WASP : A Model of Generation Planning

- Output:
  - REPROBAT (Report Writer of WASP in a Batched Environment)
  - Writes a report summarizing the total or partial results for the
    - Optimum
    - or Near Optimum power system expansion plan
    - and Fixed Expansion schedules
  - We get a *Least Cost Generation Expansion Plan* with Optimum Energy Mix of
    - Hydro; big medium and small of all types
    - Thermal: all types with different fuel types
    - Nuclear

Additional Features in EGEAS Product of EPRI

- It can model as many hydro power plants candidates as you may like
- Multi-Area Analysis
- Risk Analysis
- Plant Life Management
- Demand Side Management
- Bid-Based Market Price Analysis

Modern Generation Planning for Present Power Sector

- From being cost-minimization to profit-maximization
  - Private-Public Mix
  - Private Market
- Regulator is a bridge between Independent Power Producer (IPP), the utility and the consumers
- Comprehensive Generation Plan has to consider
  - Basket Price affordable by the consumer
  - Tariff for an IPP ensuring attractive profits

Generation Planning in Private Power Market

- Bid-Based Market
- Marginal pricing within bid-based pools with the unit dispatch based on bid prices.
- The revenue earned by each generating unit is calculated and compared against its cost to develop the net margin for the unit.
- A negative net margin would indicate that the unit is a likely retirement candidate
- Unit revenues are based on the market clearing price concept

Generation Planning in Private Power Market

- These revenues are calculated during production costing, based on bid prices and the number of hours each generating unit is the marginal unit.
- The bid price for each unit is the marginal operating cost multiplied by the user-specified bid multiplier.
- The marginal operating cost, in dollars per megawatt hours, includes the following components:

Generation Planning in Private Power Market

- Fuel
- Variable operating and maintenance cost
- Detailed costs modeled as variable O&M
- Emission allowance costs, if emission adjusters are used to modify the dispatch order
- Dispatch modifier, if modeled
- EGEAS sets the dispatch order based on the bid prices.
- For multiple-block units, EGEAS uses a levelized cost for each of the blocks

Generation Planning in Private Power Market

- Must-run blocks are treated as having a marginal cost of zero
- Higher blocks of must-run units use the actual, rather than levelized, cost.
- For hours where there is insufficient capacity (loss of load hours), EGEAS uses the cost of unserved energy as the marginal price.

Role of Renewables in Generation Planning

- Variability in the net load (Residual Load) increases due to variable generation of Renewables i.e. wind and solar
- Following are to be considered for Generation Planning Model:
  - Bankable Wind Data of wind farms to reduce deviation in forecasted generation
  - 4 hour ahead forecast rather than day-ahead forecasting
  - Increasing spinning reserve in conventional generators

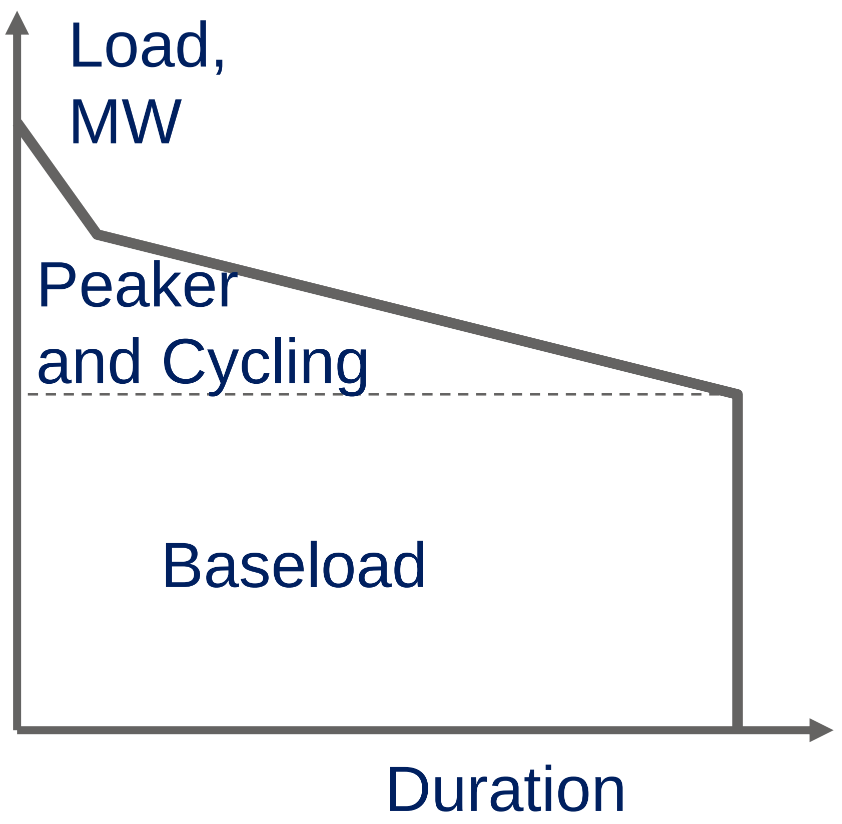
Role of Renewables in Generation Planning

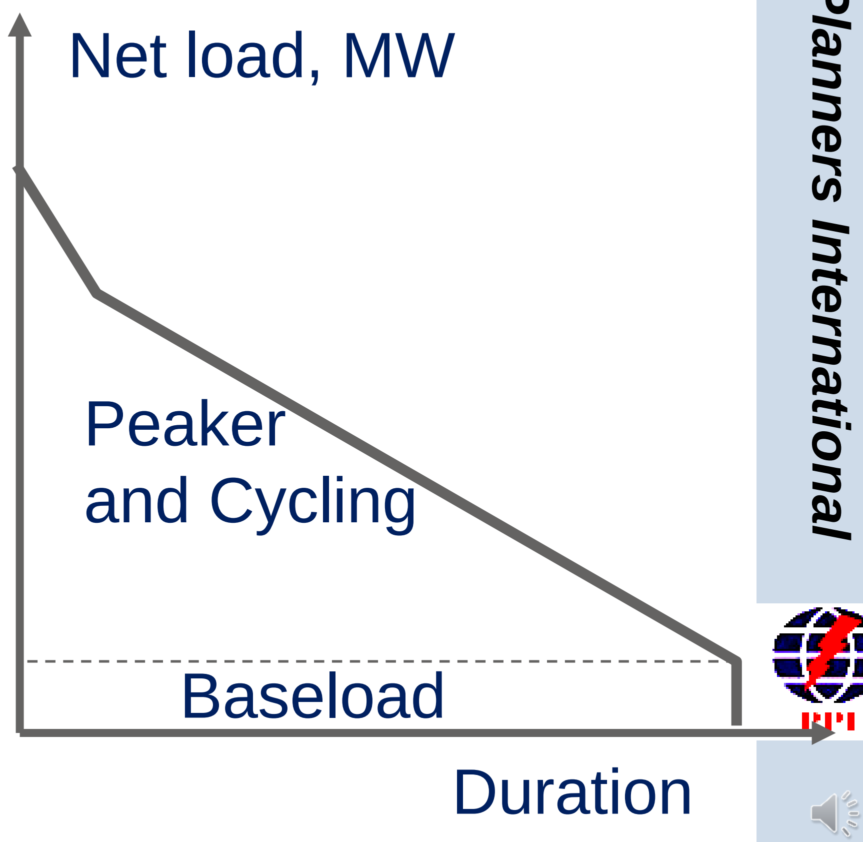
- Use of improvised battery storage to mitigate intermittency
- Offer-based economic dispatch.
- Convolve daily load curves with Solar Plants' duty cycle and evolve flexibility with conventional hydel and thermal power plant's dispatch order
- Wind and demand correlation
- WASP and EGEAS may be used by modifying Load Duration Curves to represent Residual Load (NET Load) as the load to be met

Role of Renewables in Generation Planning

Load-duration without wind.

Net Load-duration with wind.
Net load = load minus wind.





Role of Cross Border Power Trading in Generation Planning

SAARC Countries Power Trading

- Bangladesh and India 500 MW through B2B HVDC
- India to import power from Bhutan using its huge hydropower potential
- India importing and exporting power from/to Nepal
  - Muzaffarpur-Dhalkebar 400 kV HVAC (in operation)
  - Gorakhpur-Butwal 400 kV to go into construction soon
- Sri Lanka – India submarine HVDC intertie (planned)

Role of Cross Border Power Trading in Generation Planning

- Generation Planning for two or more systems are connected through Interties both for
  - Reserve sharing (emergency exchange)
  - Economy interchange (fix power exchange)
- Multi-Area Analysis in EGEAS provides modeling the effects of both

➢ Reserve Sharing:

- Interconnection model is used in determining reserve margins and loss of load probabilities.

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Role of Cross Border Power Trading in Generation Planning

- Economy Exchange:
  - Dispatcher's hour-by-hour decisions in real time are replaced by simulated interchanges based on a probabilistic determination of the availability and cost of economy interchanges.
  - Modeling, which can be performed with annually or seasonally, affects only the production cost and unserved energy, the reserve margin and LOLP are unaffected.

Role of Cross Border Power Trading in Generation Planning

➢ Tie-line limitations

- These are specified in terms of a capacity (MW) and a capacity factor (percent).
- Analysis is not performed on an hourly basis, a capacity constraint is imposed where the limiting value is the product of the capacity, capacity factor, and the number of hours in the time period.
- If the energy transfer is only in one direction during a time period, then the energy constraint is modeled exactly.

Role of Cross Border Power Trading in Generation Planning

- If there are transfers in both directions, however, some of the transfers may cancel each other and the constraint is modeled only approximately.
- Tie-line limits can be specified for each system and different limits can be applied for sales and purchases; the limits can vary from year to year.

Conclusions

- Generation Planning in SAARC Countries requires to consider
  - Classical Least Cost Generation Plan
  - Private-Public Partnership and open bidding market
  - Upcoming big penetration of Wind and Solar Power
  - Cross-Border Power Trading
- A Comprehensive Generation Plan integrating geographically contiguous SAARC member states may be evolved. It will go a long way to benefit all the stakeholders in the Region

Thank You
For Your Attention

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