Workshop on
ANALYZING AND MANAGING THE IMPACT OF VARIABLE RENEWABLE ENERGY ON THE GRID WORKSHOP
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What studies should be performed to assess the impact of VRE on System Operations?

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Agenda

- Purpose of the UCED study
- Process
- Inputs and outputs
- Questions answered
Purpose of Study 1: Unit Commitment and Economic Dispatch (UCED) Simulation

- System Operator optimizes the power supply cost through the daily unit commitment and hourly economic dispatch of all generators.
- VRE can have a significant impact on this, and the purpose of study 1 is to simulate the UCED process for future scenario years with planned or targeted amount of VRE generation.
- It is also called Production Cost Modeling.
The purpose of study 1 is to analyze the impact of VRE on:

- Unit commitment and economic dispatch (UCED) of conventional generators
- Operating parameters of conventional generators: operating efficiency, amount of time operating close to minimum capacity factor, cycling, PPA dispatch and operation terms, GHG emissions
- Operating parameters of transmission lines: congestion
- Type and amount of flexible generation required from existing or new generators to integrate VREs into grid operations
- Cost of integration of VRE. Scope of cost: additional cost due to operating generators are inefficient load factors and use of more expensive generation (peakers and other flexible generators)
1. Detailed model of the grid in a software like DIgSILENT Power Factory or Plexos.
   - Since the focus of the study is on dispatch of conventional generators, the grid model’s focus:
     - operational and contractual constraints
     - cost of generation and its various components
     - static properties of elements like generators and transmission lines

2. Run UCED simulation hour-by-hour (or finer granularity of say 30 minutes) for a whole year
   - Merit order dispatching with all the constraints is performed. In most cases the UCED model
     minimizes the production cost while attempting to satisfy all the constraints.
   - All the constraint violations are identified (if any) hour-by-hour.
   - Iterative: The modeler then evaluates a variety of options to relax the constraints and then
     rerun the model
   - This results in hour-by-hour dispatch of all the generators in order to meet the hourly load
Study 1 Overview

1. Constraints Modeling
   - Generator limits
   - T line limits
   - Contracts/PPA
   - Hydro
   - Maintenance schedule
   - Others

2. Unit Commitment Economic Dispatch

3. Balance Demand/Supply and Satisfy All Constraints?

Potential Impact of VRE
- Flexibility needs of thermal/hydro units:
  - Lower capacity factor
  - Shut down/start up
  - High ramp rate
- Methods of accessing flexibility
- Amount of RE Curtailment
- Limits on Ramping
- Additional cost of energy
- Others
Study 1 Process

Baseline & Scenario specific Model building & verification & validation → Run all scenarios → Compile results → Develop alternative solutions and rerun scenarios

Assess generation flexibility adequacy → Assess grid adequacy requirement → Assess increase in cost of dispatching conventional generators → Develop recommendations

Alternatives are:
• Storage
• Curtailment of VRE
• Additional flexible generation
• Demand response
Study 1 Input, Output

- UCED Simulation process:
  - Full year simulation of Unit Commitment and Economic Dispatch
  - Hourly or sub-hourly depending on dispatching granularity
  - Check if any constraints are violated and resolve them

- Input:
  - Demand, VRE generation forecast
  - Transmission capacity
  - Maintenance schedules
  - Constraints (more details)

- Output:
  - Resource adequacy (more details)
  - Grid adequacy (more details)
## Example of Constraints

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Capacity (MW)</th>
<th>Technical constraints</th>
<th>Contractual constraints</th>
<th>Production cost</th>
</tr>
</thead>
</table>
| Nuclear | 1,100 | Min CF: 50%  
Ramping: 5%/min  
Min up time: 8 hrs  
Min down time: 24 hrs | Max/Min monthly/annual units  
Max/Min CF  
Bi-lateral contracts | Generation cost  
Ramping cost  
Start-up/shut-down cost  
Marginal cost curve |
| Coal SPP | 2x400 | Min CF: 40%  
Ramping: 4%/min  
Min up time: 4 hrs  
Min down time: 6 hrs | Max/Min monthly/annual units  
Max/Min CF  
Bi-lateral contracts | Generation cost  
Ramping cost  
Start-up/shut-down cost  
Marginal cost curve |
| Gas SPP | 2x300 | Min CF: 40%  
Ramping: 6%/min  
Min up time: 3 hrs  
Min down time: 4 hrs | Max/Min monthly/annual units  
Max/Min CF  
Bi-lateral contracts | Generation cost  
Ramping cost  
Start-up/shut-down cost  
Marginal cost curve |
| CCGT | 3x290 | Min CF: 50%  
Ramping: 10%/min  
Min up time: 2 hrs  
Min down time: 2 hrs | Max/Min monthly/annual units  
Max/Min CF  
Bi-lateral contracts | Generation cost  
Ramping cost  
Start-up/shut-down cost  
Marginal cost curve |
| OCGT | 3x180 | Min CF: 40%  
Ramping: 20%/min  
Min up time: 1 hrs  
Min down time: 1 hrs | Max/Min monthly/annual units  
Max/Min CF  
Bi-lateral contracts | Generation cost  
Ramping cost  
Start-up/shut-down cost  
Marginal cost curve |

For a more comprehensive list, see: [https://core.ac.uk/download/pdf/34627483.pdf](https://core.ac.uk/download/pdf/34627483.pdf)
Illustration of Study 1 Sample Result

Source: https://www.energy.gov/sites/prod/files/2016/02/f30/EPSA_Power_Sector_Modeling_FINAL_021816_0.pdf
What kinds of questions does Study 1 answer?

- How often and for how long are constraints violated and reason for violations: bilateral contracts, contractual minimum, technical minimum, ramp rate, congestion, etc.?
- How much balancing capacity (inter-dispatch interval) is required to manage planned VRE penetration? How would Russia and Central Asia be used for balancing?
- How much power would flow in inter-regional transmission lines? Would there be congestion?
- What is the expected curtailment of VRE?
- What is the cost of integrating VRE into the grid for different VRE penetration scenarios?
- What would be the benefits of changes to the current methodology of dispatching—reduction of dispatch interval, Automated Dispatching System and VRE forecasting?
- Should planned VRE plants be delayed or relocated because of balancing and other issues?
- What should be the changes to PPA and grid code to clarify issues like amount of curtailment, VRE forecasting process and desired accuracy, deviation settlement and others?
- Evaluate various scenarios for feasibility and cost:
  - Different penetration of VRE, different mix of solar and wind, different locations
  - Procurement of new flexible generation, retirement of old inflexible plants and retrofits of existing plants
Develop Recommendations

The final step is to develop recommendations in the following areas:

• Allowable VRE penetration levels and associated mitigating measures
• Amount and type of additional flexibility required from existing generation capacity
• Amount and type of new flexible generation capacity requirement
• Alternative strategies to increase penetration of VRE and associated cost: Curtailment of VRE generation during specific hours, energy storage, demand response and others
• Potential adverse impact of higher penetration of VRE and the associated cost of VRE integration
Thank You

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