Suggestions for new structure for Electricity in MARKAL

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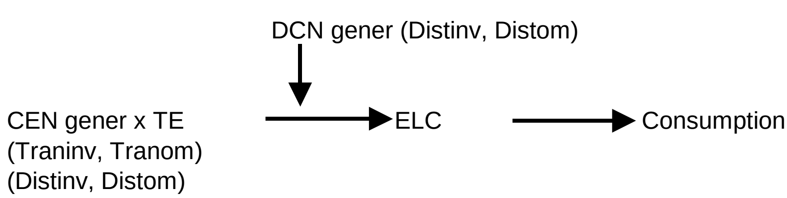
Standard Grid Representation



Grid Control

- Energy balance equations:

$$TE \times \sum_{CEN} Generation + \sum_{DCN} Generation \geq Consumption$$

- Peak equations (only written for SD, WD, ID (optional)):

$$[TE \times \sum_{CEN} Cap \times PeakF + \sum_{DCN} Cap \times PeakF] \times \frac{31.536}{(1 + \mathrm{Re}\, serve)} \geq \sum Demands$$

Problems

- Transmission and distribution costs added to generation costs
  - May have different lifetimes between plant types or infrastructure and power plants
    - Infrastructure depreciated at different rates depending on power plant lifetime
  - Transmission and distribution development pattern different to generation
  - Note: T/D costs comparable to power station costs

- MARKAL “Transmission” efficiency covers both transmission and distribution
  - Difficult to allow correctly for losses
    - In reality distribution loss dominates (say 10% vs 3 – 5 % transmission)
  - May want to separate the two components e.g. plant close to consumption centre
  - Can’t account properly for plant located near load centre (may want to include distribution loss but no transmission loss)

Problems (cont'd)

- Difficult to set up electricity interconnections
  - In MARKAL export is after TE most of which is distribution loss
    - To compensate must have "unusual" entries for flows into interconnectors that are not obvious
- Same reserve applies to distribution, transmission and generation
  - A large part of generation reserve is for plant unreliability that does not apply to same extent to transmission and distribution
- MARKAL peaking equation only covers the day period but this is not reliable when there is large import of electricity or plant such as solar that does not operate at night (i.e. varying MARKAL peak factor).
- The model only allows entry of a single peaking factor signifying contribution to peak capacity but this may vary seasonally (e.g. for biomass plant) or diurnally (e.g. for solar plant)
- Issues become increasingly important with more distributed generation

New Representation

- Transmission and distribution systems represented explicitly as "T/D" technologies
- Investment and O&M costs for transmission and distribution associated with those technologies
- Separate transmission and distribution losses
- Generation plant can supply to transmission (CEN), distribution (DCN) or directly to load (on-site)
  - Indicated by electricity output
- Old CEN/DCN now makes no difference but still useful for viewing purposes (perhaps introduce new "ONSITE" category)
- Peak factor dependent on time division
- Equations written for all time divisions

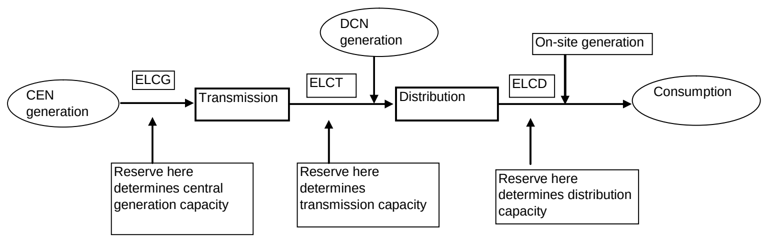
Varying Peak Factor

- Standard MARKAL peaking equations may not work correctly if peak factor varies for different time divisions
  - For solar, PF might be 1 during day but zero in evening
  - If peak in evening put PF = 0
  - But if peak normally during day must put PF = 1 but then evening period may not then be correctly modelled (PF also incorrectly put at 1)
- Getting the peak factor correct will become much more important if renewables (particularly solar) provide a significant part of generation capacity

Examples

- Vietnam
  - 3 grids with interconnection
  - Possible large power imports
  - A large part of existing plant is diesel located on outskirts of load centres
- Other ASEAN countries
  - Biomass only available during harvesting season
  - Possible large use of solar
  - Electricity interchanges may be substantial

New Grid (incl. on-site generation)



Notes

- Location of plant in system determined from OUT(ELC)_TID entry
- Require equations to determine distribution, transmission and generation capacity
- Various combinations are possible depending on system (although system as modelled next slide will always be correct)
  - Example: If peak-factor of DCN generation not dependent on time division AND no on-site generation, can use standard MARKAL structure for ELCT
- Could consider more voltage levels e.g. distribution above and below 22 kV

General Equations

Distribution:

$$[\sum_{On-site} Cap \times PeakF(z,y) + Cap(Distr)] \times \frac{31.536}{(1+\mathrm{Re}\,serve_D)} \ge \sum Demands(z,y)$$

Transmission:

$$[\frac{1}{(1+DL)}\sum_{DCN} Cap \times PeakF(z,y) + \sum_{On-site} Cap \times PeakF(z,y) + \frac{1}{(1+DL)} Cap(Trans)] \times \frac{31.536}{(1+\mathrm{Re}\,serve_T)}$$
$$\ge \sum Demands(z,y)$$

Generation:

$$[\frac{1}{(1+TL)(1+DL)}\sum_{CEN} Cap \times PeakF(z,y) + \frac{1}{(1+DL)}\sum_{DCN} Cap \times PeakF(z,y) + \sum_{On-site} Cap \times PeakF(z,y)$$
$$+\frac{1}{(1+TL)(1+DL)}\frac{PeakF(z,y)}{(QHR(z,y)\times 31.536} \times \mathrm{Im}\,pelc(z,y)$$
$$-\frac{1}{(1+TL)(1+DL)}\frac{PeakF(z,y)}{(QHR(z,y)\times 31.536} \times Expelc(z,y)] \times \frac{31.536}{(1+\mathrm{Re}\,serve_G)} \ge \sum Demands(z,y)$$

Notes

- PeakF(z,y) dependent on (z,y)
- Different reserves for distribution, transmission and generation
- Equation should be written for all time divisions
- Not all possible terms shown
- Under various circumstances equations can be simplified
  - Possible to use existing equations if CEN generation only (but with extension to all time periods and PF (z,y) dependent

Equations (cont'd)

- May want to include demands at different voltage levels
- Transmission example

$$[\frac{1}{(1+DL)}\sum_{DCN} Cap \times PeakF(z,y) + \sum_{On-site} Cap \times PeakF(z,y) + \frac{1}{(1+DL)} Cap(Trans)] \times \frac{31.536}{(1+\mathrm{Re}\,serve_T)}$$

$$\geq \sum Demands_D(z,y) + \frac{1}{(1+DL)} \sum Demands_T(z,y)$$

Implementation

- Equations may appear complex but in fact very similar to standard MARKAL peaking equations except additional CAPs included with appropriate losses as move upwards towards generation
- At each level must decide
  - Which energy carrier is used to define demand
  - Which plants further down the system are included
  - Appropriate values for DL and TL
- Coding could be very similar to present except include additional plants

Compatibility

- Probably desirable if compatible without changes to existing databases
- One suggestion is to identify a new item, say T/D then a pre-processing stage would determine the plants to be included in the MARKAL peaking equations by looking whether the energy carrier is input into a T/D component
  - If so move down system until answer is negative recording information
    - For ELCD would note just this carrier with loss unity and demands obtained from ELCD
    - For ELCT would note energy carrier ELCT with loss (1+DL) and energy carrier ELCD with loss unity and demands obtained from ELCD
    - Etc

Compatibility (cont'd)

- To be compatible with existing databases, losses here are in addition to those associated with energy carriers but would expect latter to be unity if using new structure.
- Likewise if present, transmission and distribution costs associated with energy carriers would be treated just as they are now
- When writing new equations include all generation plant with output in the list but only include T/D plant with output at the highest level
  - Example, include Distr in equation for ELCD but not for ELCT

Reporting

- Would be informative if additional information was provided on electricity pricing
- At moment get marginal energy for each time division plus peak charge
  - Even with this is desirable if peak charge is converted to equivalent energy charge then single weighted average (preferably volume-weighted) calculated
    - Then much easier to compare electricity price between cases
- Do same for new structure giving price at each level
  - No details here but needs care
- Another very useful report would be production contribution in each time division by technology