Business from technology

Recent Enhancements in TIMES (v3.4.2 — v3.8.1)

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Presentation Outline

- The MACRO Decomposition Algorithm
- Residual Load Curves
- Constraints for Operation Limits
- Timeslice-Dynamic User Constraints
- Constraining Storage Flows by Capacity
- New Reporting Options
- Other Minor Enhancements
- Documentation Status

The MACRO Decomposition Algorithm

- MACRO is a simple general equilibrium model for TIMES
  - Maximizes an inter-temporal Negishi-weighted utility function for a single representative producer-consumer agent in each region
  - Useful for estimating the macro-economic implications of policies
- Decomposition into TIMES+MSA offers efficient integration
  - Now feasible to use MACRO even for a global TIMES model
  - Calibration hugely faster than with original TIMES-MACRO
- Recent improvements to TIMES-MSA:
  - Some numerical problems have been reduced/eliminated
  - Climate Module forcing functions updated during master iterations
  - Cost-Benefit analysis now supported, as in the Merge model (market and non-market damage due to climate change)
  - Makes TIAM-Macro a full-blown Integrated Assessment Model

Residual Load Curves

- Integrating large amounts of variable renewable generation
- Level of non-dispatchable electricity curtailment must be kept below a certain limit, and sufficient peak capacity ensured
- Storage capacity must accommodate downward variation of demand and upward variation of non-dispatchable generation:

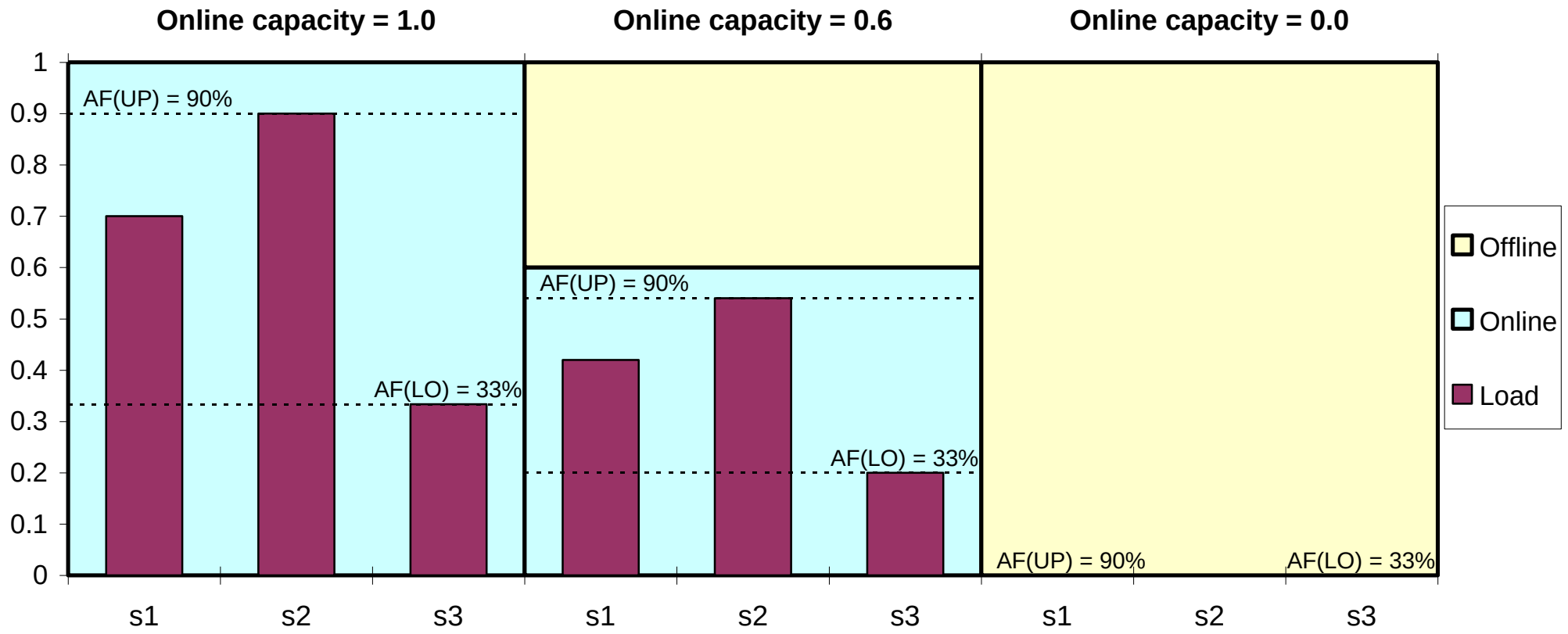
$$\sum_i AF_{i,j}^{stg} \cdot CAP_i^{stg} \geq P_j^{th\text{-}min} - (1 - VAR_j^{res-}) \cdot L_j^{res} + \sum_k VAR_j^{k+} \cdot P_{j,k}^{non-disp}$$

- Dispatchable peak load capacity should accommodate upwards variation of residual load and downwards variation of non-dispatchable generation:

$$\sum_i AF_{i,j}^{disp} \cdot CAP_i^{disp} + \sum_i AF_{i,j}^{stg} \cdot CAP_i^{stg} \geq (1 + VAR_j^{res+}) \cdot L_j^{res} + \sum_k VAR_j^{k-} \cdot P_{j,k}^{non-disp}$$

Technology Operation Limits

- Defining minimum activity levels too rigid with NCAP_AF(LO)
  - Allow for seasonal unit commitment with startup / shutdown
- Dynamic ramping constraints may also need to be imposed



Ramping Constraints

- For many technologies, activity transients are constrained
  - Constraints may be imposed by the technology itself, environmental regulations, or system requirements
  - E.g. power plants (thermal, hydro, wind etc.)
- Ramping constraints now available for limiting the speed of increase / decrease in activity level between timeslices
- Unit: Fraction of nominal capacity per hour
- Input parameter: ACT_UPS(r,y,p,s,bd)
  - UP – limit for ramp-up
  - LO – limit for ramp-down
  - FX – flexible lower bound on activity (see prev. slide)
- Parameter is levelized to the process timeslices

Timeslice-Dynamic User Constraints

- New type of user constraint introduced for dynamic user constraints between successive timeslices
- Timeslice level specified by UC_ATTR / UC_TSL :
  - UC_ATTR(r,uc_n,side,uc_grp,tslvl) (in VEDA-FE)
  - UC_TSL(r,uc_n,side,tslvl) (in ANSWER-TIMES)
- RHS values must be specified by UC_RHSRTS
  - Values are levelized to the timeslice level specified
- All timeslice-specific terms in the constraints automatically divided by the year fraction G_YRFR(r,s) of the timeslice on both sides → refer to “load levels”
- Easy to define both timeslice-dynamic equations (side=RHS) and static and flow-capacity relationships (side=LHS)

Constraining Storage Flows by Capacity

- In TIMES, capacity normally bounds only the activity
  - For storage, this means the amount of stored energy
- With NCAP_AFC, one can bound the output flows instead
  - For storage, this means the discharge flows, e.g. electricity produced by a pumped hydro plant
  - Capacity then also refers to the output capacity, e.g. electrical capacity of pumped hydro power plant
- Input flows and activity may also need to be bounded:
  - If input/output commodities are different: NCAP_AFC(input)
  - If input=output, NCAP_AFC(NRG) can be used for input, while NCAP_AFC(output) defines the availability factor for output
  - NCAP_AFC(ACT) can be used for bounding the activity

Reporting Options – Levelized Costs

- Levelized cost can be calculated according to the following general formula:

$$LEC = \frac{\sum_{t=1}^{n} \frac{IC_t}{(1+r)^{t-1}} + \frac{OC_t + VC_t + \sum_i FC_{i,t} + FD_{i,t} + \sum_j ED_{j,t}}{(1+r)^{t-0.5}} - \frac{\sum_k BD_{k,t}}{(1+r)^{t-0.5}}}{\sum_{t=1}^{n} \frac{\sum_m MO_{m,t}}{(1+r)^{t-0.5}}}$$

r = discount rate (e.g. 5%)
IC_t = investment expenditure in (the beginning of) year t
OC_t = fixed operating expenditure in year t
VC_t = variable operating expenditure in year t
FC_{it} = fuel-specific operating expenditure for fuel i in year t
FD_{it} = fuel-specific acquisition expenditure for fuel i in year t
ED_{jt} = emission-specific allowance expenditure for emission j in year t (optional)
BD_{kt} = revenues from by-product k in year t (optional)
MO_{mt} = output of main product m in year t

Reporting Options – Miscellaneous

- Levelized production costs (previous slide)
  - RPT_OPT('NCAP','1') = –1 / 1 / 2
- Reporting of Net Present Value (NPV):
  - RPT_OPT('OBJ','1')
- Split of investment costs according to Hurdle Rates
  - RPT_OPT('OBJ','1')
- Electricity supply by energy source
  - RPT_OPT('FLO','5')
- “Levelised” annual cost reporting
  - $SET ANNCOST LEV
  - All annual costs levelised over period years
  - When used with OBLONG, objective can be reconstructed

Other Minor Enhancements in TIMES

- NCAP_START for adjusting process availability
- Peak contribution of net imports – use PRC_PKNO+PKCNT
- Peak contribution of CHP by capacity – use PRC_PKAF
- Flow-based max. availability equations – NCAP_AFC
  - Any non-PG flow can be bounded by capacity
  - PG flows can optionally be also independently bounded
- Option for filling parameters via centered averaging
  - Activate with $SET WAVER YES
  - Dense interpolation followed by weighted-centered averaging
  - Only COM_PROJ and PRC_RESID for now
- Semi-continuous investment variables supported
  - Define lower bound by NCAP_SEMI(r,y,p)

Documentation Status

- Updated: Document on the TIMES Control Switches
- Updated: Documentation of TIMES-MSA
- New: Documentation of grid modeling features
- New: Documentation of residual load curve features
- New: User Note on Timeslice-Dynamic User Constraints
- Base documentation and supplementary notes:
  - Documentation for the TIMES Model (Parts I-III)
  - User Notes on various TIMES enhancements
  - Require some updating (project for doc updates starting?)
- All documentation available at the ETSAP website:

www.iea-etsap.org