# CC Modeling

MSWG

April 12, 2005

Robert de Mello

# CC Modeling Plan

1. Seek input from CC owner/operators to fully understand characteristics and limitations of units.

   1.a Report results of (1) to MPs

2. Develop Feasible alternatives in conjunction with ABB
   – Scheduling (optimizing) the operating state and/or
   – Detecting the operating state and making allowances for physical limitations.

We are here → 2.a Report results of (2) to MPs.

# CC Modeling Plan

3. Select model characteristics in conjunction with MPs. (These may be obvious choices)

4. Implementation, tariff filing, testing and deployment.

# Topics

- The Mod-and-Transition model
- Day-Ahead Scheduling
- Real-Time Tracking
- Real-Time Scheduling
- Your feedback is important:
  - Can this approach be applied to your plant?
  - What are the market or individual benefits of changes to the unit commitment process?
  - Are the benefits of major changes to the scheduling systems worth the cost of the changes?

# Recap: Operating States

- Startup / Warming HRSG and possibly ST
  - No control capability
  - Synchronized and producing energy at a fairly low level
  - May take several hours
  - Must warm HRSG and ST slowly
- Normal Operation
  - Able to control output
  - Control range approximately top 30 % of unit capability – (Varies)
  - Fairly responsive within its control range

# Recap: Current System

- Day-Ahead characteristics that must be accommodated:
  - Hourly bids/offers for a one-day period
  - One-day optimization period
  - One-hour commitment/scheduling decisions
- Real-Time characteristics that must be accommodated:
  - Hourly bids/offers for a one-hour period
  - ~2.5 hour (RTC) or ~1 hour (RTD) optimization period
  - 15-minute (RTC) commitment/scheduling decisions
  - 5-minute scheduling decisions (RTD)

# Mod-and-Transition Model

- A **MOD** is a particular configuration or operating state of a plant, for example:
  - 1st CT starting (and HRSG/ST warming)
  - 2nd CT starting (and HRSG warming)
  - Normal operation with 1 CT
  - Normal operation with 2 CTs
- A **TRANSITION** is the switch from one Mod to another.

# Mod's Information

| Information Describing a Mod | | |
|---|---|---|
| **Symbol** | **Description** | **Units** |
| $FD_m$ | Flag indicating whether plant is dispatchable in mod "m" | Y/N |
| $FR_m$ | Flag indicating whether plant is able to supply regulation in mod "m" | Y/N |
| $FS_m$ | Flag indicating whether plant is able to supply spinning reserve in mod "m" | Y/N |
| h | Index of hour of the day (0, 1, 2, 3, ...) | 0,1,2,... |
| $IE_{m,h}$ | Incremental energy offer curve of plant in mod "m" for the hour beginning "h" | $/MWH vs MW |
| m | Index of the plant and its mod (operating configuration) | - |
| $MGC_{m,h}$ | Hourly cost for plant in mod "m" to operate at its minimum generation level for the hour beginning "h" | $/hr |
| $MGL_{m,h}$ | Minimum generation level of plant in mod "m" for the hour beginning "h" | MW |
| $MNRUN_m$ | Minimum run time of the plant in mod "m." Perhaps minimum run time can be expressed as a function elapsed time since another transition occurred. | hr |
| $MXRUN_m$ | Maximum run time of the plant in mod "m." Perhaps maximum run time can be expressed as a function elapsed time since another transition occurred. | hr |
| $RE_m$ | Emergency ramp rate of the plant in mod "m" | MW/min |
| $RN_m$ | Normal ramp rate of plant in mod "m" | MW/min |
| $RR_m$ | Regulation ramp rate of plant in mod "m" | MW/min |
| $UOLE_{m,h}$ | Emergency upper operating limit of plant in mod "m" for the hour beginning "h" | MW |
| $UOLN_{m,h}$ | Normal upper operating limit of plant in mod "m" for the hour beginning "h" | MW |

# Transition's Information

| Information Describing a Transition | | |
|---|---|---|
| **Symbol** | **Description** | **Units** |
| h | Index of hour of the day (0, 1, 2, 3, …) | 0,1,2,… |
| m | Index of the plant and its mod (operating configuration) | - |
| m1 | Prior mod (the configuration prior to the transition) | - |
| m2 | After mod (the configuration after to the transition) | - |
| $TC_{m1,m2,h}$ | Cost of the transition from mod "m1" to mod "m2" for the hour beginning "h." Perhaps cost of a transition can be expressed as a function elapsed time since another transition occurred. | $ |

# Other Information

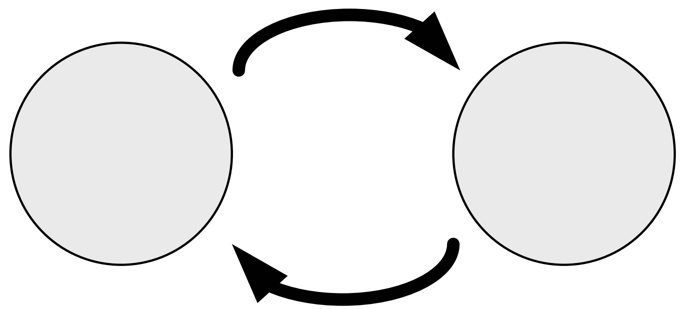
| Other Information | | |
|---|---|---|
| **Symbol** | **Description** | **Units** |
| $MXSTOP_p$ | Maximum stops per day for plant "p" | 0,1,2,… |
| $MNDOWN_p$ | Minimum down time before plant "p" can be started again. | hr |
| $MNRUN_p$ | Minimum run time of the plant "p." A plant's minimum run time can be assured by careful selection of mods and transitions. This is illustrated below for a two-on-one plant. | hr |

# Day-Ahead Scheduling
## Feedback Needed

- What quantifiable market or individual benefits would justify major modifications to the day-ahead scheduling systems?
- Could your plant adequately be represented by start-up and running states?
- Is this model too simple to accurately represent your plant for day-ahead scheduling?
- Will you be able to adequately represent your plant's minimum run time?
- Is this model too complicated to use?
  - Would you ever figure out how to bid the plant?

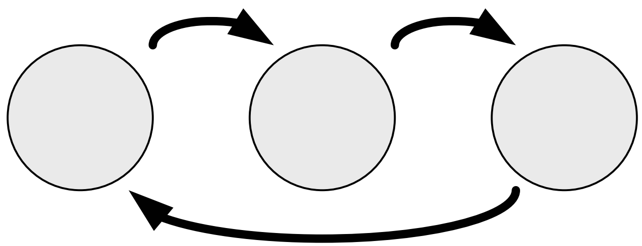
# Day-Ahead Scheduling

## Two Mod Plant



In the mod-and-transition terminology, all power plants are currently represented with an "OFF" and a "RUNNING" mod. Transitions are called "START-UP" and "SHUT DOWN."

# Day-Ahead Scheduling
## One-on-One CC Plant



| Mod: Running | |
|---|---|
| FD | Yes (typical) |
| FR | Yes (typical) |
| FS | Yes (typical) |
| IE | Reflects plant's marginal cost |
| MGC | Reflects plant's cost |
| MGL | 70% of plant capacity (typical) |
| MNRUN | 8 hours (typical). |
| MXRUN | ∞ (typical) |
| RE | 1% MW/min (typical) |
| RN | 1% MW/min (typical) |
| RR | 1% MW/min (typical) |
| UOLE | 100% of plant capacity (typical) |
| UOLN | 100% of plant capacity (typical) |

| Transition: Off-to-Starting | |
|---|---|
| m1 | "Off" mod |
| m2 | "Starting" mod |
| TC | Plant's start-up cost. Typically this should not include expected payments for energy produced during the "starting" mod. Start-up cost may depend on the elapsed time since the CT-HRSG was shut down. |

| Mod: Starting | |
|---|---|
| FD | No (likely) |
| FR | No (likely) |
| FS | No (likely) |
| IE | Reflects plant's marginal cost |
| MGC | Reflects plant's cost at the specified minimum generation level |
| MGL | 10% of plant capacity (typical) |
| MNRUN | Start up takes 1, 2, or 3 hours (typical). |
| MXRUN | The plant must leave the "starting" mod after 1, 2, or 3 hours (typical). |
| RE | 0.5 MW/min (typical) |
| RN | 0.5 MW/min (typical) |
| RR | 0.5 MW/min (typical) |
| UOLE | 10% of plant capacity (typical) |
| UOLN | 10% of plant capacity (typical) |

| Transition: Starting-to-Running | |
|---|---|
| m1 | "Starting" mod |
| m2 | "Running" mod |
| TC | $0.00 (likely) |

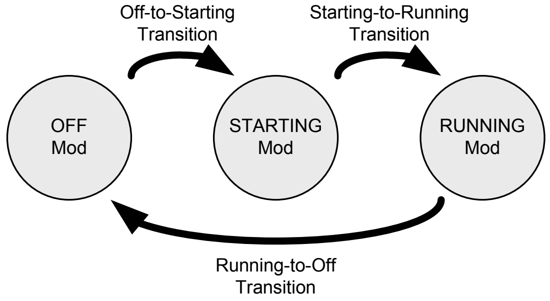
| Transition: Running-to-Off | |
|---|---|
| m1 | "Running" mod |
| m2 | "Off" mod |
| TC | $0.00 (likely) |

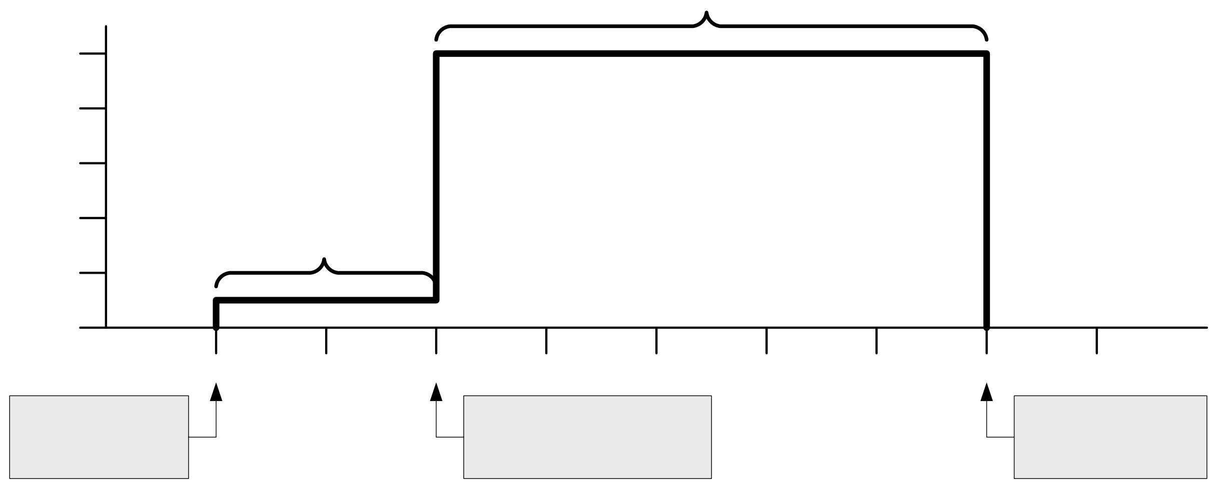
Off-to-Starting Transition

Starting-

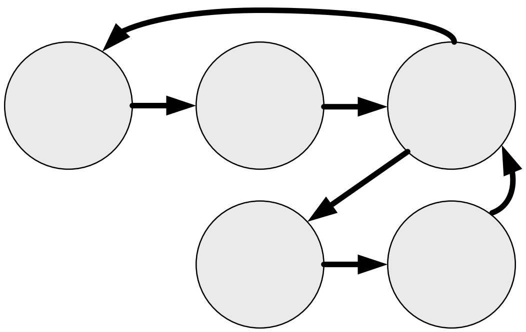
Tra

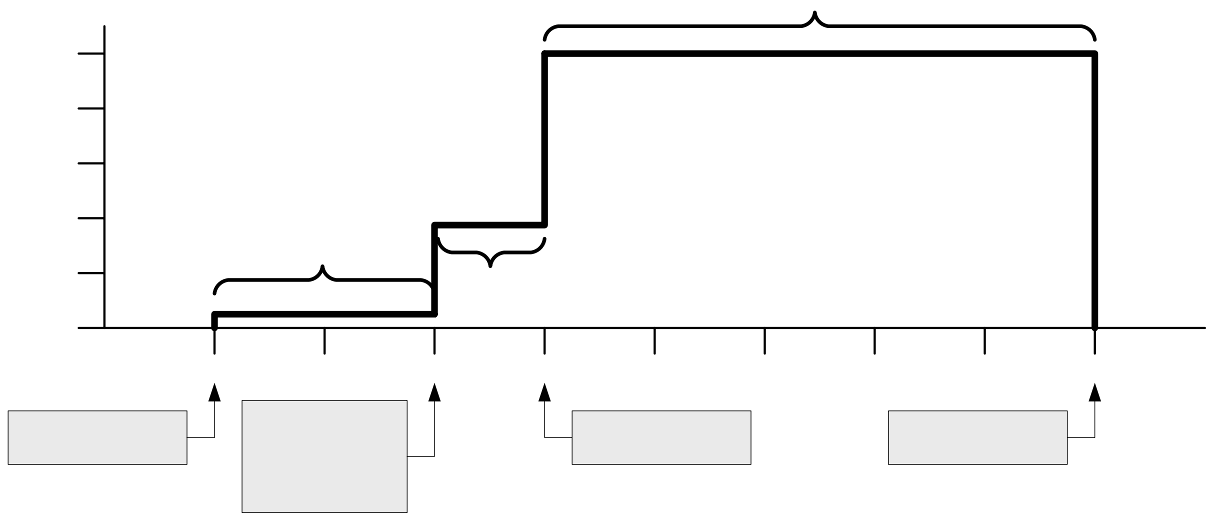
# Day-Ahead Scheduling
## One-on-One CC Plant



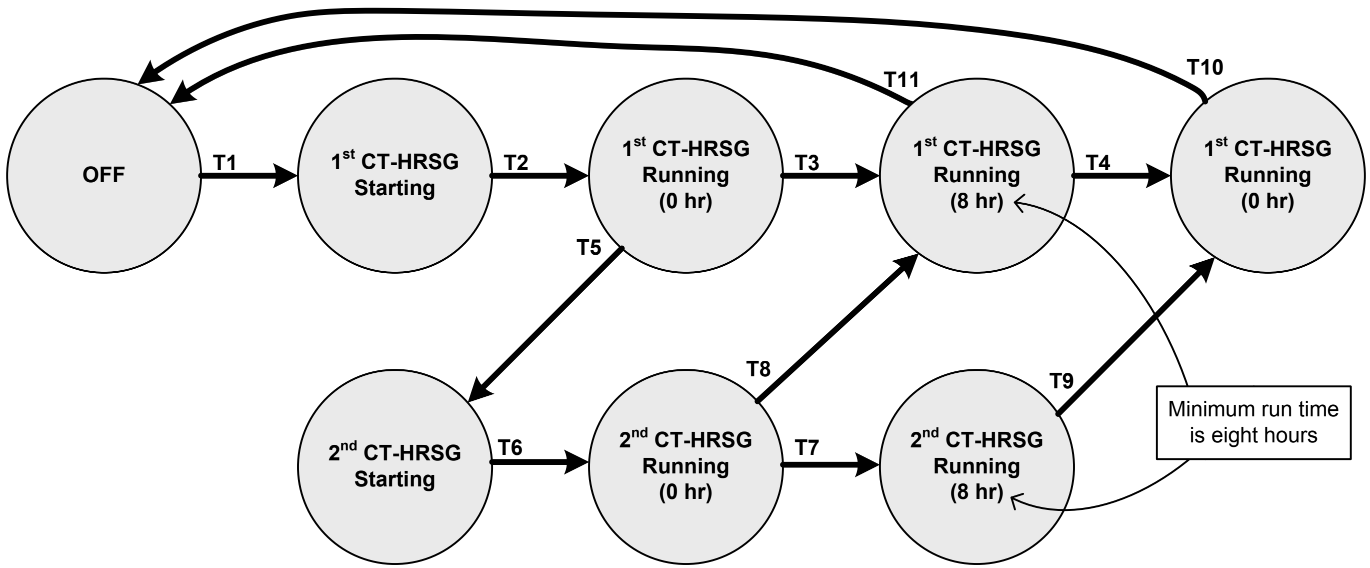



# Day-Ahead Scheduling
## Two-on-One Plant

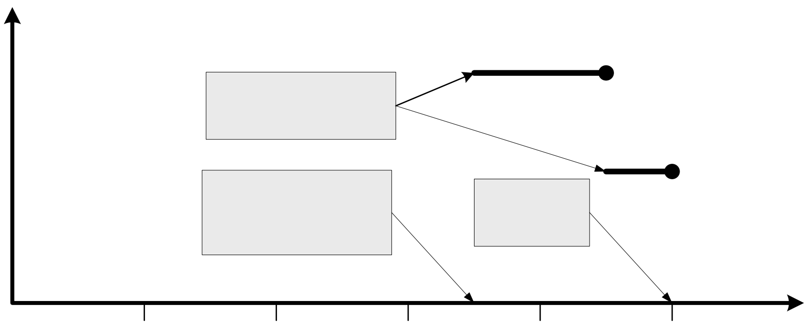


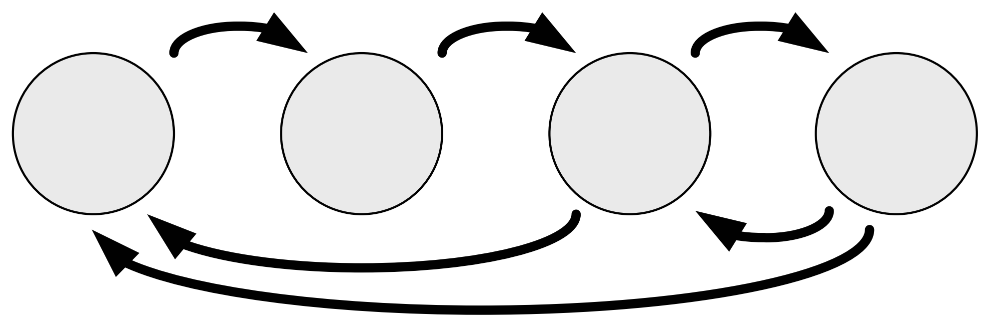


# Day-Ahead Scheduling
## Two-on-One Plant with 8-Hour Minimum Run Time



# Day-Ahead Scheduling
## Non-Monotonic Incremental Cost





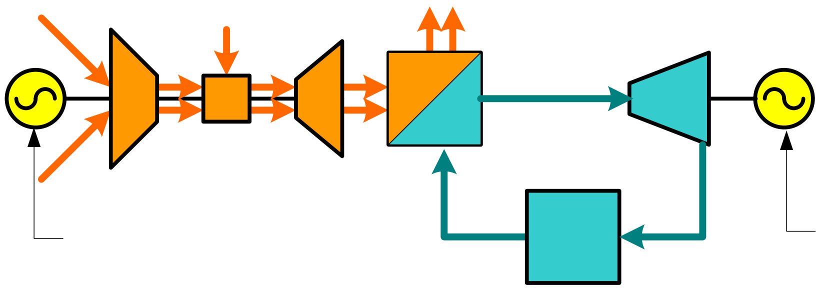
# Real-Time Tracking
## Feedback Needed

- Should the NYISO infer the state of your plant from measurements; or should your plant's operator notify the NYISO of your plant's current operating state?
- Can the current operating state of your plant be inferred solely from measurement of its generators' real power?
- Will additional plant instrumentation be needed?
- What are the benefits of automating the detection of a plant's operating state?
  - Are benefits enough to justify implementation costs?
- Will something this simple work for your plant?

# Real-Time Tracking

- Automatically detect the current operating state of a plant
- Dispatch the plant only when it is able to respond, treat the plant as self-scheduled otherwise
- Schedule ancillary services only when plant is able to provide those services
- Cannot easily predict a plant's capabilities in the near future

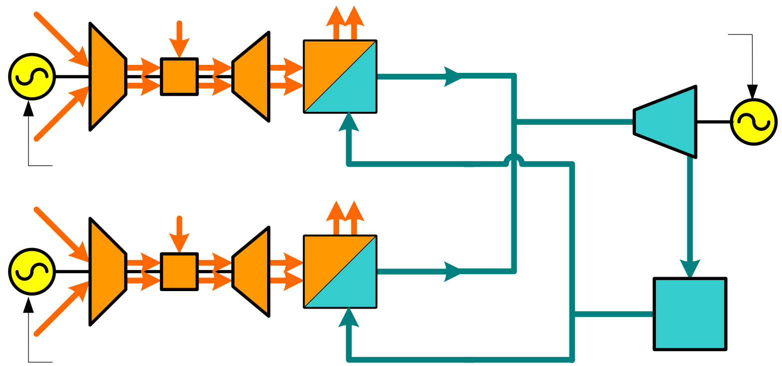
# Real-Time Tracking
## One-on-One CC Plant



- Measure output of the CT generator
- Assume the plant will not run for any length of time as simple-cycle CT

| | Condition | Mod |
|---|---|---|
| CT1off | $CTGen < T_1$ | "Off" mod. The first threshold represents some minimum generation level, perhaps 2% of the CT's capacity |
| CT1start | $T_1 \le CTGen \le T_2$ | "Starting" mod |
| CT1run | $CTGen > T_2$ | "Running" mod. The second threshold might be 65% or 70% of the CT's capacity, a value that represents the minimum continuous operating level of the CT. |

# Real-Time Tracking
## Two-on-One CC Plant



| CT1 State | CT2 State | Plant Mod |
|---|---|---|
| CT1off | CT2off | "Off" |
| CT1off | CT2start | "First CT-HRSG starting" |
| CT1off | CT2run | "First CT-HRSG running" |
| CT1start | CT2off | "First CT-HRSG starting" |
| CT1start | CT2start | Impossible state – two CT-HRSGs cannot start simultaneously |
| CT1start | CT2run | "Second CT-HRSG starting" |
| CT1run | CT2off | "First CT-HRSG running" |
| CT1run | CT2start | "Second CT-HRSG starting" |
| CT1run | CT2run | "Second CT-HRSG running" |

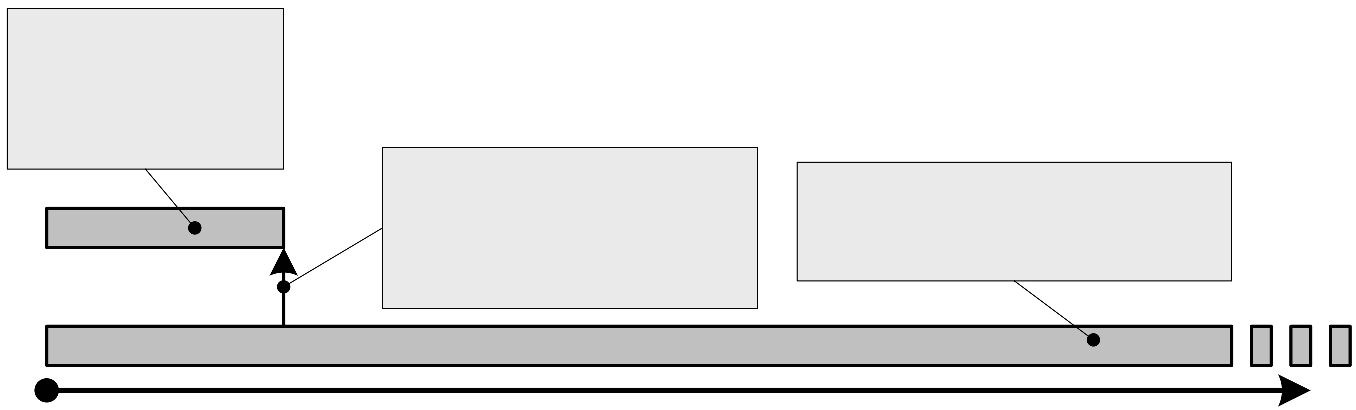
# Real-Time Commitment
## Feedback Needed

- What are the benefits of having RTS schedule transitions among valid operating states in real-time?
- Does the mod-and-transition model adequately represent your plant for RT operation?
- Is the mod-and-transition model too difficult to use?

# Real-Time Scheduling

- In real-time, the NYISO would schedule each transition from one operating state to another
  - 15 minutes (or more) advanced notification
- RTS optimization windows are too short to adequately accommodate minimum and maximum run times
  - Some type of auxiliary optimization process is needed.

# Real-Time Scheduling



- Initial state could be measured
- Auxiliary optimization would set RTC & RTD "end states"
- DA schedule might be an acceptable auxiliary optimization
  - RT conditions might be enough different from DA conditions that deviations from DA results are warranted
  - Auxiliary optimization might have to be rerun periodically

RTC optimization window

# Issues & Options

- Interim –
  - Relief from performance penalties
- Longer term –
  - DA Schedule
  - RT tracking of plants' operating states
  - RT Scheduling