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Power System Operation and Control

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Implementation of New Dispatch Formulation and Software for Tertiary Frequency Control Reserves in Indian Power System

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Motivation

- Tertiary Frequency Control operational in the Indian Power System in the form of Reserves Regulation Ancillary Services (RRAS) since April 2016.
- Real Time Market (RTM) and revised scheduling gate closure timelines implemented from 1st June 2020 – restricting dispatch to 30 minutes.
- Automating dispatch and ensuring certainty of reserves dispatch while harnessing the technology infrastructure developed for Security Constrained Economic Dispatch (SCED).

Approach

- Optimization based approach to dispatch RRAS at least cost
- Dispatch after scheduling gate closure – resulting in certainty of reserves dispatch
- Automating data exchange and incorporation in schedules – remove need for manual intervention
- Ensure full utilization of available reserves

Background

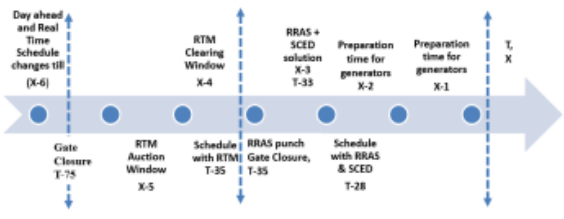
- Ancillary Services for operationalizing tertiary frequency control reserves were introduced in April 2016 in the form of Reserve Regulation Ancillary Services (RRAS). An in house software application in place to implement RRAS.
- Scope for improvement in terms of dispatch efficiency and user-friendliness.
- Security constrained economic dispatch (SCED) introduced in Apr 2019 to act as a centralized optimization layer over a decentralized scheduling framework.
- To operationalize SCED, significant automation and integration of the scheduling process at national level was carried out and dedicated communication channels and APIs were established between NLDC and RLDCs

Gap Analysis Of RRAS Implementation until 2020

- Recall by original beneficiaries resulting in non-scheduling of dispatched RRAS, as RRAS dispatch window straddled beyond gate closure boundary.
- Requirement of manual inputs and telephonic confirmation in dispatch and incorporation of RRAS in net schedules of generators within tight scheduling timelines
- Data exchange reliability issues due to usage of older technologies like FTP and CSV files

Scheduling Timelines

- RTM implemented from 1st June 2020 - thirty minutes' delivery period in two consecutive fifteen-minute time blocks at regular intervals during the day.
- To bring in firmness in the schedule and transactions in real-time, Gate Closure has been introduced.
- SCED is another window of optimization for a particular time block after the RTM window for that time block has closed.
- RRAS dispatched after clearing of RTM, 35 minutes before delivery



- X is the delivery time block
- T is the start of the delivery period (in minutes)
- RTM: Real Time Market
- RRAS: Reserve Regulation Ancillary Services

C2

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Continued

Mathematical Formulation for RRAS Dispatch

Decision Variable:

- $RRAS_g$: *RRAS dispatch for g^{th} generator (in MW)*

Objective function:

- *Minimize the cost of RRAS dispatch*

$$\sum_g (RRAS_g * VC_g) + Violation\ Penalties$$

Subject to constraints:

i. Satisfy reserve requirement:
$\sum_g RRAS_g = RRASdisp$

ii. Max generation limit: $\forall g, Sch_g + RRAS_g \leq Pmax_g$

iii. Min generation limit: $\forall g, Sch_g + RRAS_g \geq Pmin_g$

iv. Ramp up limit: $\forall g, Sch_g + RRAS_g \leq OldOptSch_g + RampUp_g$

v. Ramp down limit: $\forall g, Sch_g + RRAS_g \geq OldOptSch_g - RampDown_g$

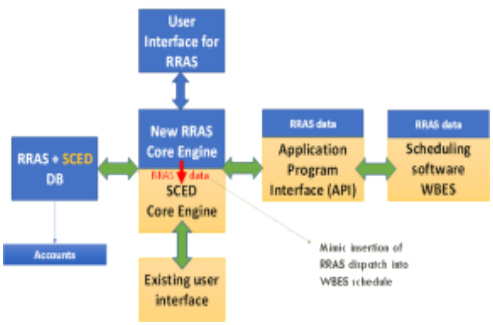
vi. Unidirectionality:

vii. *if (RRASreq > 0)*: $\forall g, RRAS_g \geq 0$

viii. *if (RRASreq = 0)*: $\forall g, RRAS_g = 0$

ix. *if (RRASreq < 0)*: $\forall g, RRAS_g \leq 0$

Integration of RRAS & SCED Software



Notation

- *g* is the set of generators;
- VC_g is the variable charge of g^{th} generator (in INR/kWh);
- $Pmax_g$ & $Pmin_g$ are the maximum and minimum generation limits (in MW);
- $RampUp_g$ and $RampDown_g$ are the ramp up and ramp down limits (in MW/15 min);
- Sch_g is the injection schedule of g^{th} generator (in MW);
- $OldSch_g$ is the un-optimized injection schedule of g^{th} generator in the previous time block (in MW);
- $OldOptSch_g$ is the final optimized schedule in the previous time block (in MW);
- *OldRRASUp* & *OldRRASDn* are the total RRAS Up and Down dispatched in the previous time block (in MW);
- *RRASreq* is the net tertiary reserve dispatch required in the current time block decided by the system operator (in MW).
- *ResUpAvail* & *ResDnAvail* are the 15-minute ramp constrained up and down reserve available (in MW/15 min):

$$\boldsymbol{ResUpAvail} = \sum_g \min(Pmax_g - OldOptSch_g, RampUp_g) - (\sum_g Sch_g - \sum_g OldSch_g)$$

$$\boldsymbol{ResDnAvail} = \sum_g \min(OldOptSch_g - Pmin_g, RampDown_g) + (\sum_g Sch_g - \sum_g OldSch_g)$$

- *RRASdisp* is the net tertiary dispatch requirement for the current time block, restricted to the available ramp limited reserves:

$$\boldsymbol{RRASdisp} = \max(\min(RRASdisp, OldRRASUp + ResUpAvail), OldRRASDn - ResDnAvail)$$

C2

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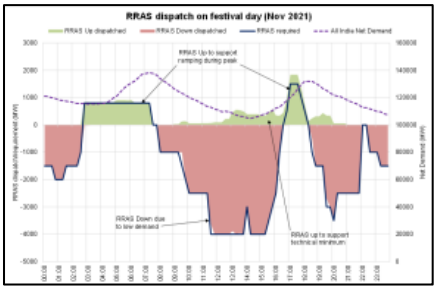
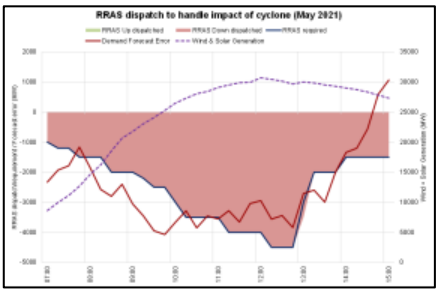
User Interface for application of RRAS

Handling of critical events

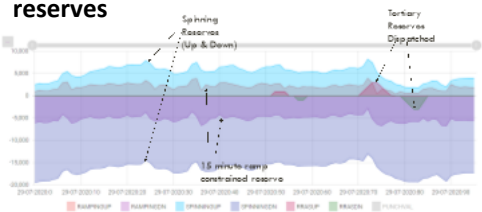




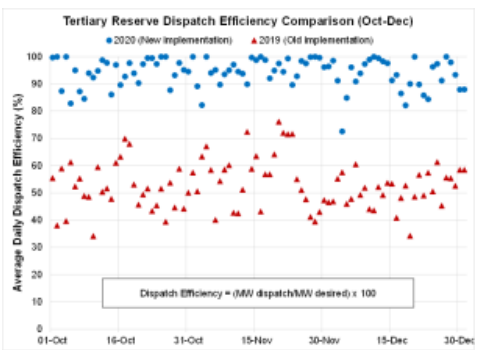
Key Features

- Input of RRAS requirement by the System Operator
  - RRAS quantum for any block can be entered/ modified/ withdrawn ahead of time
- Run timings
  - the RRAS core engine runs 2 time-blocks ahead of the actual dispatch in the 12th minute, just before SCED core engine
- Reserves Calculation
- Technical Minimum / Turndown Level Support
  - To activate units under cold reserve
- Modelling of multi-fuel Gas stations
  - Framing fuel-wise and plant level constraints

Trend of available & dispatched reserves



Improvements in RRAS dispatch



Way Forward

- New features are being added to the software as requirements are identified by system operators.
- Better estimation of the quantum of reserves to be dispatched.
- New market-based ancillary products and procurement of reserves to be implemented in near future