संदभं संख्या: पोसोको/एनएसडीसी/2019/

दिनांक: 19th August, 2019

सेवा में,

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केंद्रीय विद्युत नियामक आयोग (सीईआरसी), तीसरा तथा चौथा तल,
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संदभं: CERC communication no. RA-14025(13)/2/2019-CERC dated 09th August, 2019

महोदय,

With reference to the above mentioned communication, the feedback report on experience gained from the SCED of ISGS pan-India was sought.

In this direction, an interim feedback report on Pilot on Security Constrained Economic Despatch (SCED) of ISGS pan-India is enclosed at Annexure – I for kind information. Further, as directed in the order dated 31st January, 2019 in Petition No. 02/SM/2019, a detailed feedback report on pilot on SCED is under preparation and would be submitted in due course.

It is submitted that in order to understand the complexities involved in the co-optimization of energy and ancillary services, there is a need for additional time-period to test this aspect on pilot basis. Moreover, the SCED Pilot has been running during the summer/monsoon seasons of April to September 2019 and there is a need for gaining experience during the winter season. Therefore, the Central Commission is requested to consider and issue appropriate directions to extend the pilot on SCED for ISGS pan-India for six more months i.e. upto 31st March 2020 along with implementation of co-optimization of SCED and Reserve Regulation Ancillary Services (RRAS).

सादर धन्यवाद,

भवदीय,

(देवाषिश दे)
मुख्य महाप्रथाधिक

संलग्न: As above
Pilot on
Security Constrained Economic Despatch (SCED)

Interim Report

August, 2019
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1.0 Background

Hon’ble CERC vide Order in Petition No. 02/SM/2019 (Suo-Motu) dtd. 31st January, 2019, directed implementation of a Pilot on Security Constrained Economic Despatch (SCED) in Inter-State Generating Stations (ISGS) Pan India with effect from 01st April, 2019. SCED has been implemented for all the thermal Inter State Generating Stations (ISGS) that are regional entities and whose tariff is determined or adopted by the Central Commission for their full capacity honouring the existing scheduling practices prescribed in the Grid Code.

2.0 Implementation of SCED Pilot

Implementation of SCED pan-India in two months’ time was a challenge task considering that scheduling exercise happens in a decentralized fashion at the five Regional Load Despatch Centres (RLDCs). The state utilities and ISGS have full freedom to revise their requisitions and DC respectively upto 4th time block ahead of the delivery block which effectively means up to 30 minutes before delivery. This freedom has been retained while executing the pilot on SCED.

Figure 1: Data Exchange Timelines in Pilot on SCED
Earlier RLDCs were involved in the scheduling process on standalone basis in the respective regions. The pilot on SCED gave NLDC a major role to be associated in the scheduling process directly and for implementation of SCED, a scheduling server has been made available at NLDC for collation of schedules and data exchange with the RLDCs. Scheduling related data is exchanged with the RLDCs multiple times as per the timelines shown in Figure – 1 above.

The multi-fuel based (gas stations using domestic gas, RLNG, liquid fuels) ISGS have been excluded to begin with, as one physical station is using multiple fuel types (domestic gas, RLNG, liquid fuels) and therefore, there is an added complexity on account of unit commitment/open or closed cycle operation to be factored in real time.

Multiple inputs are going into the SCED algorithm being executed at National Load Despatch Centre (NLDC) every fifteen minutes such as Declared Capability, Normative On bar capacity, Injection Schedules, Ramp up and ramp down Rates, Variable Charges (as declared in RRAS), Technical Minimum (as per IEGC provisions), Inter-Regional Schedules and Inter-Regional Transfer Margins. Fig. 2 indicates the data flow and software outline implemented by POSOCO through in-house efforts. The Optimization core engine is using GAMS software, licence for which is provided by M/S World Bank.
The optimal schedule for the SCED generators is relayed to the RLDCs for incorporation into the ISGS schedules, normally, 13 minutes before the despatch interval begins. Exceptions may be encountered during communication delays, which typically get reported by generators. Typical schedule and optimal schedule for a typical day for a generating station is illustrated in Fig. 3.

![Figure 3: Typical Schedule and Optimal Schedule in a day for a generating station](image)

### 3.0 Mathematical Formulation of the Economic Despatch Model

The mathematical formulation of the economic despatch model being used in the pilot on SCED is enclosed at Annexure - I. The SCED model can become infeasible if there exists no solution that satisfies all of the constraints. Some of the root cause reasons identified for creation of infeasible conditions for the present model are System Ramp Rate (National), IR Schedule exceeding Transfer Capability Limits along with finite Reserves (Regional) and Individual Generator Ramp Rate (Local).

In order to address these concerns and based on operational experience gained, the optimization algorithm was improved so as to make it more robust to deal with
infeasibility and ride through within the given constraints in real time. The
infeasibilities are being tackled through the classical technique of adding artificial
variables to the constraints and penalising the objective function to that extent. The
penalty factors for handling infeasibility were taken as around ₹ 13/kWh (greater
than the cost of liquid fuel) for schedule equality constraint violation, around
₹4.33/kWh for ramping constraint violation i.e., one-third of the cost of the liquid fuel
(and greater than the highest thermal variable cost) and around ₹ 26/kWh for
Available Transfer Capability constraint violation i.e., two times the cost of liquid fuel.
The updated version of the software has been deployed with effect from 14:45 hours
of 18th April 2019. The analysis of duals that have emerged would be submitted in
the detailed report.

4.0 Highlights of Pilot on SCED

The highlights of Pilot on SCED for the period between 01\textsuperscript{st} April, 2019 – 28\textsuperscript{th} July,
2019 are as follows:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Title</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Number of Participant Generators</td>
<td>49 Nos. (Coal &amp; Lignite based)</td>
</tr>
<tr>
<td>2.</td>
<td>Number of Generating Units</td>
<td>132 Nos.</td>
</tr>
<tr>
<td>3.</td>
<td>Total Installed Capacity (MW)</td>
<td>55,940</td>
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<tr>
<td>4.</td>
<td>Average System Marginal Price (SMP) (Paisa/Unit)</td>
<td>298.27</td>
</tr>
<tr>
<td>5.</td>
<td>Decrease in Number of Revisions in Plants</td>
<td>- 43 %</td>
</tr>
<tr>
<td>S.No.</td>
<td>Title</td>
<td>Remarks</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>6.</td>
<td>Percentage Decrease in Quantum of Revisions (in MW) in Plants</td>
<td>- 34 %</td>
</tr>
<tr>
<td>7.</td>
<td>Daily Average Perturbation (in MW)</td>
<td>1276</td>
</tr>
<tr>
<td>8.</td>
<td>Charges to be paid to SCED Generator (in ₹ Crore) (01st April – 28th July, 2019)</td>
<td>759 (Avg. approx. ₹ 6.3 Cr./day)</td>
</tr>
<tr>
<td>9.</td>
<td>Charges to be refunded by SCED Generator (in ₹ Crore) (01st April – 28th July, 2019)</td>
<td>1149 (Avg. approx. ₹ 9.6 Cr./day)</td>
</tr>
<tr>
<td>10.</td>
<td>Net Variable Charges Payable(+)/- Receivable - Reduction in fuel cost (in ₹ Crore) (01st April – 28th, 2019)</td>
<td>(-)389 (Avg. approx. ₹ 3.3 Cr./day)</td>
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<tr>
<td>11.</td>
<td>Heat Rate Compensation payable (in ₹ Crore) (April – July, 2019) (only for SR)</td>
<td>58.28 (Avg. approx. ₹ 0.5 Cr./day)</td>
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</table>

Note: RPCs Accounts released upto 28th July, 2019

5.0 Data and Analysis

5.1. Variable Cost of Generation before and after SCED for a sample day

The variable cost of generation before and after SCED for a sample day is depicted in Fig. 4.
Variable cost of generation after SCED is only slightly lower than the cost of generation before SCED, as a broad merit order stacking is already being followed in the ISGS requisitions by states and RLDCs in scheduling. Also, effect of demand pattern could be observed.

Figure 4: Variable Cost of Generation before and after SCED for a sample day

5.2. System Marginal Price (SMP)

The trend of SMP for months of April, May, June and July, 2019 is depicted in Fig. 5, 6, 7 and 8 respectively.

System marginal price of SR in April’19 was higher than the rest of the grid because of high demand in SR and congestion in transmission corridors towards SR.

Figure 5: SMP for month of April, 2019
Congestion in transmission towards SR eased compared to April’19 in May’19. Slight congestion towards NR in the evening/night peak.

Transmission congestion towards NR, NER and SR in the evening/night peak hours.

Figure 6: SMP for month of May, 2019

Figure 7: SMP for month of June, 2019
5.3. Pre-SCED and Post-SCED Cost in ₹ Crore (Apr – Jul, 2019)

The pre-SCED and Post-SCED cost of production for the period April - July, 2019 in terms of ₹ Crore and paisa/kWh is depicted in Fig. 9 and 10 respectively.
Figure 10: Pre-SCED and Post-SCED Cost in paisa/unit (Apr – Jul, 2019)

5.4. Average Perturbation (in MW) through SCED (Apr – Jul, 2019)

The average perturbation for the period April - July, 2019 in MW is depicted in Fig. 11.

Figure 11: Average Perturbation (in MW) through SCED (Apr – Jul, 2019)
### 6.0 Summary of SCED Accounts

Table 1: Generator-wise Summary of Accounts (01st April – 28th July, 2019)

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>SCED Generator</th>
<th>Region</th>
<th>Variable cost (Paisa/kWh)</th>
<th>Increment due to SCED scheduled to VSCED (MU) (A)</th>
<th>Decrement due to SCED scheduled to VSCED (MU) (B)</th>
<th>Charges To be Paid to SCED Generator from National Pool (SCED) (in ₹ Cr) (C) = (A) x V.C.</th>
<th>Charges To be Refunded by SCED Generator to National Pool (SCED) (in ₹ Cr) (D) = (B) x V.C.</th>
<th>Net Charges Payable (+) / Receivable (-) (in ₹ Cr) (E)* = (C) – (D)</th>
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<td>KSTPS7</td>
<td>WR</td>
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<td>KSTPS I&amp;II</td>
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<td><strong>3,647</strong></td>
<td><strong>759</strong></td>
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<td><strong>-389</strong></td>
<td><strong>1,149</strong></td>
<td><strong>-389</strong></td>
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7.0 Summary of Benefits derived from Pilot on SCED

7.1. Optimization of Generation based on Merit Order

It is being observed that generally, the lower variable cost pit head generation is being increased in Northern Region and Eastern Region whereas the higher variable cost generation is being decreased in Southern Region. Further, the ramping from the higher variable cost generators is being done only when absolutely needed. Therefore, the pilot on SCED has led to optimization of the generation across India thereby saving production costs.

7.2. Reduction in Fuel Costs

Around ₹ 389 Crores reduction in fuel cost for April – July’19 period has been facilitated by pilot on SCED. Considering a base of approx. INR 24,000 crores, around 1.5 % reduction in generation cost (without considering heat rate compensation) has been observed. There is reduction of about ₹ 3.3 paisa in the average variable cost of generation during the April – July 2019 period.

7.3. Ease of Generators’ Operations

During the period April – July, 2019, it has been observed that there has been 43 % reduction in number of schedule changes and 34 % reduction in schedule MW changes. It has resulted in increased PLF in cheaper power stations & vice versa. Therefore, pilot on SCED has facilitated the ease of generators’ operations.

7.4. Harnessing Diversity

It has been observed that, generally, during the holidays / weekends time period, there is increased reduction in fuel costs. Further, during extreme weather conditions, load crash results in schedule revised to technical minimum within the region and therefore, diversity of the generation mix pan-India is harnessed.

7.5. Expanding the Ambit

After operationalization of pilot on SCED, two generators namely NTPC Gadarwara – 1 x 800 MW (03rd June, 2019) and Tata Power MPL - 2 x 525 MW – 1050 MW (12th June, 2019) were incorporated in the SCED optimization process. Major challenge
was to incorporate these generators in the software application and interfacing without any disruption to the on-going SCED process every 15-minute time block. Successful incorporation of these generators has increased the confidence on the robustness of the SCED software application.

7.6. Handling congestion
The split in regional system marginal prices represents periods of transmission congestion.

8.0 Summary of Challenges
8.1. Information Technology and Data Interfacing
The in-house development of software application for pilot on SCED was undertaken by the team of people pan-India across NLDC/RLDCs. The validation the data exchange and information protocols is done on day to day basis. The data interfacing is a major challenge as there were different Web Based Energy Scheduling System (WBES) across the RLDCS. There is a need for robust and seamless communication.

8.2. Communication and Integration of Regional Scheduling Software Applications
Huge effort was put in integration of WBES across all regions with automatic schedule preparation in each time-block. The synchronization of ISGS schedules pan-India required development of API at NLDC to exchange data with WBES of all 5 RLDCs. With the tight data exchange & processing timelines, the hardware and software had across all RLDCs/NLDC had to be upgraded. The complete optimization process and data communication had to be repeated every time block in a time bound manner with execution at every step. About 180,000 parameters are being handled by SCED on daily basis.

8.3. Self-healing / Ride-through Attributes
The SCED software application had to be robust enough to run continuously in real time environment with self-healing / ride-through attributes within the given constraints in case of infeasibility. It was envisaged that there would be no manual
user intervention. In this direction, an improved optimization algorithm was formulated and the updated version of the software was deployed w.e.f 14:45 hours of 18th April, 2019. The revised Detailed Procedure was also uploaded on POSOCO website.

8.4. Operational Flexibility Provisions in SCED
During certain contingencies in the system, facilitating operational requirements of the generators as well as regulatory compliances, operational flexibility provisions were incorporated in the SCED application. Some instances include:

• All SR Generators excluded from SCED application w.e.f. 23:00 hrs on 2nd May 2019 till 1930 hrs of 3rd May 2019 in anticipation of forced outages of major links in ER-SR Corridor due to Cyclone “FANI”
• Performance guarantee tests facilitated by increasing technical minimum in SCED at BRBCL (18 Apr 2019), Kudgi (4-10 Apr 2019) and Bongaigaon (29 Apr – 1 May 2019)
• Technical Minimum increased at Dadri-II for facilitating boiler modification works (24-26 Apr 2019)
• Technical Minimum increased at MPL for facilitating PSS tuning (19 Jun 2019)
• Facilitated implementation of CERC Order on increased technical minimum for NLC units

8.5. Effect of SCED on Ramping Reserves
In the pilot on SCED, it has been observed that the available spinning reserve is being consolidated in the higher variable cost generators. The availability of reserve is being constrained by the ramping capability of generation units carrying reserve. Therefore, a reduction in the cumulative reserve quantum constrained by ramp is being observed after the SCED optimization process.

8.6. Inter-Regional Scheduling
Presently, corridor wise path specific scheduling is carried out by the Regional Load Despatch Centres (RLDCs). Inter-regional schedules are also being reconciled by the
neighbouring regions. Deviations from schedules in the actual power flows are computed based on the energy meter readings and are accounted for in the regional energy accounts.

Optimization of energy and reserves may lead to where regional injection which have an impact on the inter-regional corridor schedules. For example, schedules of pit-head cheaper stations in western region may increase and some costly load centre stations may be asked to reduce in the northern & southern regions. Power flows according to the laws of physics and corridor/path wise scheduling methodology presently being used would only be distributing the scheduled flows heuristically.

Hence, for implementation of the optimization process, it is necessary to change the scheduling methodology from corridor wise scheduling to net-injection/net-drawal for each region. This would require amendments to the ‘Scheduling and Despatch Code’ under the Indian Electricity Grid Code (IEGC).

8.7. Need for Gate Closure

In the present framework, revision of schedules by the market participants is permitted and as per the ‘Scheduling and Despatch Code’ under the Indian Electricity Grid Code (IEGC), the schedules can be revised by giving a notice of four (4) time blocks (each of 15-minutes). Given the large number of participants, there are requests for revisions in schedule on an almost continuous basis. This also poses problems in real time assessment of the available ‘hot’ and ‘cold’ reserves available in the system.

In the near future, it is necessary that ‘gate-closure’ be introduced. Conceptually, prior to gate closure, the flexibility of revising the schedules is with the market participants and post gate closure, the system operators take over and prepare for the pre-determined delivery period. The introduction of gate closure will bring in more certainty of despatch especially in terms of reserves requirement & activation thereof.
9.0 Reviews and Stakeholder Consultations

9.1. High Level Reviews
Two high level reviews were conducted by the policy makers and regulators after the operationalization of the pilot. Secretary, Power had taken a review of the pilot on SCED on 15th May, 2019. Subsequently, on 03rd July, 2019, Chairperson and Members of the Central Commission had a detailed interaction at NLDC on implementation and insights from pilot on SCED.

9.2. Regional Power Committees (RPCs)
After Central Commission order in January, 2019, NLDC/RLDCs representatives had detailed interactions with all the stakeholders in respective RPCs. The details of interactions held in different RPCs are NRPC (Delhi) on 12th February, 2019, WRPC (Mumbai) on 11th February, 2019, SRPC (Bengaluru) on 12th February, 2019, NERPC (Agartala) on 14th February, 2019 and ERPC (Mejia-DVC) on 21st February, 2019.

9.3. SCED Generators
There were detailed interactions with the generators participating in the pilot on SCED on 22nd & 25th March, 2019.

9.4. Interaction with Academia and Think-tanks
There is a constant interaction on various operational and implementation aspects of pilot on SCED between POSOCO and academia such as Prof. Anjan Bose, Washington State University, USA, Prof. Abhijit Abhyankar, IIT-Delhi, Prof. Rohit Bhakar, MNIT, Jaipur, Prof. Saumen Majumdar, IIM- Tiruchirappalli, World Bank – Dr. Debabrata Chattopadhay and Dr. Puneet Chitkara.

9.5. Workshops
There were a series of workshops conducted for optimization through GAMS and hands-on training. One workshop was organized with World Bank - Dr. Miklos Bankuti (12 – 14 February, 2018). A training Program on "Implementation of Optimization Techniques for Indian Power System Operation" from 17th – 19th September, 2018 was also conducted by Dr. Kailash, Banasthali Vidyapeeth and his team at NRLDC, Delhi.
10.0 Sharing of the Residuals on Account of SCED

It is proposed that the residuals in National Pool Account (SCED) accrued due to reduction in fuel costs of generators on account of optimization process through pilot on SCED may be shared to the following stakeholders:

1) **State Utilities** - The state utilities may be given a share in proportion to the total drawl schedule or entitlements by the beneficiaries from the generating company which is also in line with the formulation by MoP policy. (Refer Ministry of Power Scheme on “Flexibility in Generation and Scheduling of Thermal Power Stations to reduce the cost of power”

   https://powermin.nic.in/sites/default/files/webform/notices/Merit%20Order%20Operation.pdf

2) **Generation ISGS** – The respective generation ISGS may also be given a share based on performance and the heat rate compensation. The incentive can be based on higher ramp (>1 %/min) and lower technical minimum (< 55 %).

   (Refer CERC (Terms & Conditions of Tariff) Regulations, 2019)

3) **Transmission ISTS** – Adequate transmission is a key enabler to the economy caused through the SCED optimization process. The insights obtained from SCED may be used to give a share to encourage development of efficient transmission planning and secure grid operation through simulation tools, modelling infrastructure and related hardware.

4) **Innovation and Research** – Ultimately, there is a need to foster a systematic and data-driven process to strengthen human resources, learning, and skills development in the country for development of economic despatch faculty in power systems. Therefore, a share of the residuals towards promoting institutional building and strengthening may also be given. (Refer FOR CABIL report)
11.0 Way Forward

11.1. Expanding the ambit of SCED – Regional Entity generators in SCED

It is recognized that there are challenges for including all the thermal ISGS in SCED that are regional entities whose scheduling is done by RLDCs in terms of:

- Various contracts (long term, medium term and short term) entered into by a regional entity generating station whose tariff is not determined / adopted under section 62 / 63 of Electricity Act, 2003 for its full capacity. Therefore, there may be multiple rates for different types of contracts at different times of the day as entered into by the regional entity generating station. In case of SCED, there is a need for single variable charge for each regional entity generating station whose generation would be optimized based on the merit order and other constraints.

- There is a need for upfront declaration of technical parameters such as total Declared Capability (DC), Technical Minimum, Ramp-up/down rates etc. for each regional entity generating station.

- There is added complexity of multi-fuel based (gas stations using domestic gas, RLNG, liquid fuels) ISGS as one physical station is using multiple fuel types and therefore, unit commitment / open or closed cycle operation is to be factored in real time.

- In case of multi contract regional entities a single variable charge may be computed based on a single rate that may be decided by CERC or the weighted average price of the contracts or using any other mechanism needs to be specified to facilitate upfront declaration of the variable charges. To get the Pmax of the generators, the DC should be available in the WBES system.

- The generator should show its willingness to participate in SCED process. As the variable charge will be a single figure though the generator may have multiple selling price as per the contracts.
• In absence of regulation for giving heat rate compensation for IPPs (tariff not covered under EA Sec 63 & 64), RPCs will be find difficult to calculate for SCED down cases.

11.2. Co-optimization of Energy and Ancillary Services
In order to despatch reserves, presently RRAS mechanism utilises formation of a merit order stack of available reserves and dispatching the system operator demanded reserves at least two time blocks before the delivery period. This method could be improved by co-optimization of the dispatch of SCED and RRAS. The aim is to bring more certainty and efficiency in the delivery of the demanded reserve by the system operator in a cost effective manner. When energy and ancillary services are co-optimized, the schedules are not automatically segregated between the energy and ancillary service. However, in order to fit the co-optimization in the existing regulatory framework where fixed charges, variable charges and mark-up is payable for the despatch of RRAS, a methodology has to be evolved. NLDC is presently working on a suitable mechanism to implement co-optimization where RRAS would be despatched one block at a time. Spinning reserves are a key factor for co-optimization of energy and ancillary services and mandate in form of an order in the interim for the pilot and a regulatory framework in the long run is needed.

12.0 Conclusion
• The detailed report on SCED is being prepared by POSOCO and would be submitted in due course.
• In order to understand the complexities involved in the co-optimization of energy and ancillary, there is a need for additional time to test this aspect on pilot basis
• Central Commission is requested to issue appropriate directions to
  ✓ Extend the SCED Pilot for six more months unto 31st March 2020
  ✓ Allow POSOCO to implement co-optimization
**Mathematical Model**

**Objective Function**
Minimize Pan India ISGS Variable Cost

**Subject to Constraints**
Meeting Total Requisition by States from ISGS
Transmission Constraints (ATC)
Technical Minimum of Plants
Maximum Generation (DC-on-bar)
Ramp up/down rates

Minimise $\sum_{i=1}^{k} C_i P_i + \sum (Violation Penalties) \hspace{1cm} (1)$

- $k = total \ number \ of \ Plants$
- Where $C_i$ is the variable per unit cost of the $i^{th}$ Plant
- $P_i$ is the optimised scheduled power of the $i^{th}$ Plant
- Violation Penalties are computed based on constraint violations

Subject to
- $\sum_{i=1}^{k} P_i = \sum_{i=1}^{k} S_i - Schedule \ violation \hspace{1cm} (2)$
- $P_i \leq (DC \ on \ bar) \hspace{1cm} (3)$
- $P_i \geq P_{i, min} \hspace{1cm} (4)$
- $P_{i,t} \leq P_{i,t-1} + Ramp \ up \ rate + Ramp \ up \ violation \hspace{1cm} (5)$
- $P_{i,t} \geq P_{i,t-1} - Ramp \ down \ rate - Ramp \ down \ violation \hspace{1cm} (6)$
- $\forall \ r \in R, \ \sum_r (P_{i,r} - S_{i,r}) \geq min((SCHIR_r - ATC_r), 0) - ATC \ violation \hspace{1cm} (7)$

- $S$ -is the scheduled power
- $t$ -represents current time of execution
- $R$ -represents each of the regions viz., North, East, West, South and North East
- ATC -is the Available Transmission Capability of each region $R$
- SCHIR -is the Scheduled Net Interchange of the region $R$
- $P_{i, min}$ is the technical minimum for thermal power plants considered at 55% DC on bar or schedule whichever is less