Reliability Guideline:
Operating Reserve Management

Preamble:
It is in the public interest for NERC to develop guidelines that are useful for maintaining or enhancing the reliability of the Bulk Electric System (BES). The Technical Committees of NERC—Operating Committee (OC), Planning Committee (PC) and the Critical Infrastructure Protection Committee (CIPC)—in accordance with their charters¹ are authorized by the NERC Board of Trustees (Board) to develop Reliability (OC and PC) and Security Guidelines (CIPC). These guidelines establish a voluntary code of practice on a particular topic for consideration and use by BES users, owners, and operators. These guidelines are coordinated by the technical committees and include the collective experience, expertise and judgment of the industry. The objective of this reliability guideline is to distribute key practices and information on specific issues critical to appropriately maintaining BES reliability. Reliability guidelines are not to be used to provide binding norms or create parameters by which compliance to standards are monitored or enforced. While the incorporation of guideline practices are strictly voluntary, reviewing, revising, or developing a program using these practices is highly encouraged to promote and achieve appropriate BES reliability.

Purpose:
This Reliability Guideline is intended to provide recommended practices for the management of an appropriate mix of Operating Reserve, as well as readiness to respond to loss of load events. It also provides guidance with respect to the management of Operating Reserve required to meet the NERC Reliability Standards.

The Reliability Guideline applies primarily to Balancing Authorities (BAs) or, as appropriate, [Contingency] Reserve Sharing Groups, Regulation Reserve Sharing Groups, or Frequency Response Sharing Groups. For ease of reference, this guideline uses the common term “responsible entity” for these entities, and allows the readers to make the appropriate substitution applying to them when participating or not in various groups.

Definition:

**Regulation Reserve Sharing Group:** a group whose members consist of two or more Balancing Authorities that collectively maintain, allocate, and supply the regulating reserve required for all member Balancing Authorities to use in meeting applicable regulating standards.

**Frequency Response Sharing Group:** a group whose members consist of two or more Balancing Authorities that collectively maintain, allocate, and supply operating resources required to jointly meet the sum of the Frequency Response Obligations of its members.

[http://www.nerc.com/docs/pc/Board%20Approved%20PC%20Charter%20August%202011.pdf](http://www.nerc.com/docs/pc/Board%20Approved%20PC%20Charter%20August%202011.pdf)
Reserve planning has been practiced for a long time by NERC operating entities, dating back to Policy 1 of NERC’s Operating Policies. This Reliability Guideline guides responsible entities toward the best practices for management of the Operating Reserve types by dividing them into individual components to provide visibility and accountability. While the incorporation of guideline practices is strictly voluntary, reviewing, revising, or developing a process using these practices is highly encouraged to promote and achieve reliability for the BES.

**Assumptions:**

A. NERC as the FERC certified ERO\(^2\) is responsible for the reliability of the BES and has a suite of tools to accomplish this responsibility, including but not limited to: lessons learned, reliability and security guidelines, assessments and reports, the Event Analysis program, the Compliance Monitoring and Enforcement Program and mandatory NERC Reliability Standards.

B. Each entity as registered in the NERC compliance registry is responsible and accountable for maintaining reliability and compliance with the mandatory standards to maintain the reliability of the BES.

C. Entities should review this Reliability Guideline in detail in conjunction with the periodic review of their internal processes and procedures and make any needed changes to their procedures based on their system design, configuration and business practices.

**Guideline Details:**

An effective Operating Reserve program should address the following components: (I) Management Roles and Expectations; (II) System Operator Roles; (III) Regulating Reserve; (IV) Contingency Reserve; (V) frequency responsive reserve; (VI) capability to respond to large loss-of-load events; (VII) Reserve Sharing Groups; and (VIII) Operating Reserve Interaction. Each individual component should address (1) Safety; (2) Processes and Procedures; (3) Evaluation of any issues or problems along with solutions; (4) Testing; (5) Training; and (6) Communications. These provisions and activities together will be referred to as the Operating Reserve program.

---

**Definition:**

**Contingency Reserve:** The provision of capacity that may be deployed by the Balancing Authority to respond to a Balancing Contingency Event and other contingency requirements (such as Energy Emergency Alerts Level 2 or Level 3 as specified in the associated EOP standard). The capacity may be provided by resources such as Demand Side Management (DSM), Interruptible Load and unloaded generation.

**Frequency Responsive Reserve:** An amount of reserve automatically responsive to locally sensed frequency deviation.

---

Each responsible entity should evaluate the total reserve needed to meet its obligations under NERC Reliability Standards, namely regulating, contingency and frequency responsive reserve. Given the different reserves may be difficult to separate in actual operation, the system operator will need an understanding of the quantity of each type of reserve required. Each responsible entity should consider the types of resources and the associated portion of their capacity capable of reducing the Balancing Authority’s Area Control Error in either direction in response to each of the following:

1. Frequency deviations,
2. A Balancing Contingency Event,
3. Events associated with Energy Emergency Alert 2,
4. Events associated with Energy Emergency Alert 3, and
5. Large loss-of-load event.

I. Management Roles and Expectations

Management plays an important role in maintaining an effective Operating Reserve program. The management role and expectations below provide a high-level overview of the core management responsibilities related to each Operating Reserve program. The management of each responsible entity should tailor these roles and expectations to fit within its own structure.

a. Set expectations for safety, reliability, and operational performance.

b. Assure that an Operating Reserve program exists for each responsible entity and is current.

c. Provide annual training on the Operating Reserve program and its purpose and requirements.

d. Ensure the proper expectation of Operating Reserve program performance.

e. Share insights across industry associations.

II. System Operator Roles

a. Participate in appropriate System Operator training.

b. Ensure the Operating Reserve information is always current.

c. Conduct an evaluation of the effectiveness of the Operating Reserve program and incorporate lessons learned.

d. Implement the Operating Reserve program in Real-time.

III. Regulating Reserve

The responsible entity’s balance between demand, supply (generation minus metered interchange) and frequency support is measured by its Area Control Error (ACE). Because changes in supply and demand cannot be predicted precisely, there will be a mismatch between them, resulting in a non-zero ACE.
Each responsible entity should have a documented Regulating Reserve process ensuring the responsible entity has sufficient capacity to meet the performance requirements of BAL-001. The process should include at a minimum:

a. A method for determining its regulating needs. This method should take into account the entity’s generation mix, type of load, the variability in both generation and load, and the probability of extreme influences such as weather.

b. Types of resources and the portion of their capacity that can be made available for regulation. The responsible entity should have resources that will respond to the entity’s need to balance supply and demand to meet the performance requirements of NERC Reliability Standards.

c. The responsible entity should incorporate into its regulating needs consideration of contractual arrangements such as exports and imports. Changes to contractual arrangements should be assessed and accounted for in the responsible entity’s ability to respond and meet the performance requirements.

d. The responsible entity should evaluate its planned Regulating Reserve (based on changing system conditions, such as the current load, forecast errors, and generation mix) needs over the operating time horizon and gauge its ability to meet its Regulating Reserve needs on at least an hourly basis.

e. The responsible entity should plan and implement its ability to restore its Regulating Reserve as needed. This may include the ability to restore Regulating Reserve in either direction.

f. The responsible entity’s Regulating Reserve process should include a method whereby its Regulating Reserve is not included in another responsible entity’s Operating Reserve (Regulating, Contingency, or frequency responsive reserve) policy.

IV. Contingency Reserve

When a responsible entity experiences an event, i.e., loss of supply or significant scheduling problems, which can cause frequency disturbances, it should be able to adjust its resources in such a manner to assure its ACE recovers in accordance with the requirements of the applicable Reliability Standards.

a. Responsible entity’s Contingency Reserve need:

In order for responsible entities to meet the requirements of the NERC Reliability Standards they need to identify their Most Severe Single Contingency (MSSC) to determine their base Contingency Reserve. Because there is no forgiveness for this minimum amount of Contingency Reserve not deployed when called upon, additional amounts could be considered based on the individual entity’s risk analyses. To be effective, Contingency Reserve should be able to be deployed (including activation or communication needs) to meet the Contingency Event Recovery Period for Balancing Contingency Events. Reserve set aside as frequency responsive reserve should not be included in the available minimum Contingency Reserve amounts in Interconnections composed of more than one responsible entity, because at any given time, they may also be deployed and unavailable to meet the reliability requirements associated with Contingency Reserve. Additionally, an appropriate mix and coordination of
frequency responsive reserve and Contingency Reserve should be considered to ensure that the responsible entity has the ability to respond to frequency events on the Interconnection as well as in its own Balancing Authority Area, in accordance with all NERC and Regional standards.

**Definition:**

**Most Severe Single Contingency:** The Balancing Contingency Event, due to a single contingency, that would result in the greatest loss (measured in MW) of resource output used by the Reserve Sharing Group (RSG) or a Balancing Authority that is not participating as a member of a RSG at the time of the event to meet firm system load and export obligation (excluding export obligation for which Contingency Reserve obligations are being met by the sink Balancing Authority).

b. Many types of resources can be considered for use as Contingency Reserve during the five aforementioned conditions provided they can be deployed within the appropriate timeframe. As technology and innovations occur this list may continue to grow, but may include:

1. Unloaded/loaded generation
2. Off-line generation
3. Demand resources
4. Energy Storage Devices
5. Resources such as wind, solar, etc., provided any limitations are taken into account.

c. Responsible entities should consider how their Contingency Reserve would be affected by interruption of schedules, taking into account the terms and conditions under which such energy schedules were arranged.

Responsible entities that choose to use energy schedules to respond to a Balancing Contingency Event should take into account the terms and conditions under which such energy schedules were arranged and verify that they would not detract from a responsible entity’s use of such schedules when meeting their Contingency Reserve requirements for Balancing Contingency Events.

d. A prohibition against counting toward the responsible entity’s Contingency Reserve any capacity which is already included in another responsible entity’s Regulating, Contingency, or frequency responsive reserve policy. Special coordination may be required for resources that are dynamically transferred between multiple responsible entities.

e. To assure a responsible entity has the ability to respond to a Balancing Contingency Event during Real-time, the responsible entity should plan for its available Contingency Reserve for the operating time horizon (Operations Planning, Same Day and Real-time Operations). This time horizon could be multiple days to a review of the next hour’s available reserve. The review should be flexible so that it can be updated to reflect changes in the amount of reserve available or the amount of reserve required.
f. Responsible entities should consider developing some form of electronic reserve monitor, which would track resources available to provide the necessary response and the amount of capacity each could provide. Many energy management systems (EMS) currently provide this type of feature for measuring the up and down ranges of their resources. Care should be taken to recognize the up and down ranges on resources which have been made available by the purchase or sale of non-firm energy which may disappear during an event.

g. In order for a responsible entity to meet the Contingency Reserve Restoration Period, pre-planning and training of System Operators may be required. Actions such as the following may be considered:

1. Verification of status/availability of additional resources
2. Commitment of additional resources
3. Implementation of demand resources, such as interruptible loads (usually pre-arranged contractually)
4. Curtailment of recallable transactions
5. Consider the effect of emergency schedules that end before recovery completion

h. The responsible entity should exercise prudent operating judgment in distributing Contingency Reserve, taking into account effective use of capacity in an emergency, time required to be effective, transmission limitations, and local area requirements.

V. Frequency Responsive Reserve

Each responsible entity should maintain an amount of resources available to respond to frequency deviations. Planned frequency responsive reserve (day-ahead, day of and hour prior) should be available in addition to planned Regulating and Contingency Reserve. For a responsible entity experiencing a frequency deviation, frequency responsive reserve would be deployed to arrest frequency change and remain deployed until frequency is returned to its normal range. Although response is generally expected to come from on-line rotating machines, other resources (e.g., controllable load contracted for that purpose, certain energy storage devices, etc.) can provide initial and sustained response that would help to arrest frequency change and sustain frequency at an acceptable post event-level until frequency is returned within its normal range. Each responsible entity should have a documented frequency responsive reserve process ensuring the responsible entity has sufficient capacity to meet the performance requirements of BAL-003. The process should include at least the following:

a. The BAL-003-1 standard, Frequency Response and Frequency Bias Setting, specifies (in Table 1 in Attachment A) the Interconnection Frequency Response Obligation (IFRO) and the maximum delta frequency (MDF). Attachment A also provides the calculation methodology used to determine the Frequency Response Obligation (FRO) assigned to each responsible entity in a multiple responsible entity Interconnection (the responsible entity’s FRO is the same as the IFRO in a single responsible entity Interconnection). In a multiple responsible entity Interconnection, each responsible entity’s FRO is its pro-rata share of the IFRO based on the sum of its annual generation MWh plus load MWh as a fraction of those for the entire
Interconnection. The attachments and forms associated with the BAL-003 standard cover these calculations in more detail. To determine an initial target (at scheduled frequency) frequency responsive reserve level (in MW) for a given responsible entity, simply multiply 10 times the responsible entity’s FRO (because FRO is in MW/0.1 Hz) by the MDF for the responsible entity’s Interconnection. An example to illustrate this:

Given: ABC responsible entity is in the Eastern Interconnection (EI) and its pro-rata portion of IFRO is 1.5%.

The key EI parameters from Table 1 are: IFRO = 1002 MW/0.1 Hz and MDF = 0.449 Hz.

The responsible entity’s FRO is \(1.5\% \times 1002 \text{ MW/0.1 Hz}\) or 15.2 MW/0.1 Hz.

The responsible entity’s initial frequency responsive reserve target is \(10 \times 15.2 \times 0.449\) or 67.48 MW.

The initial target may need to be modified based on several factors, most of which are addressed later in this section. For example, if actual performance indicates additional response is needed, then the target should be increased. The responsible entity also may choose to perform a risk analysis in determining the level of frequency responsive reserve that assures compliance at an acceptable cost.

b. Any resource (generation, load, storage device, etc.) that is capable of responding to frequency can be a candidate for inclusion as part of a responsible entity’s frequency responsive reserve; however, such resources should help to arrest the initial frequency change (also known as primary response, and often referred to as droop or governor response) and/or provide sustained support at a post-event frequency level until frequency returns to its normal range. Moreover, the responsible entity should have an appropriate mix of both primary and secondary reserves. This is highlighted in the Lawrence Berkeley National Laboratory (LBNL) Report - Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation, Key Findings.\(^3\)

c. As long as the total of the frequency responsive reserve amounts for each responsible entity are satisfied, any amount of frequency responsive reserve may be provided through contractual agreements (within the same Interconnection) between responsible entities. This is the basis of the concept of Frequency Response Sharing Groups. Responsible entities can also contract for sheddable load that responds to frequency deviations (usually at pre-set thresholds) to provide frequency responsive reserve. Responsible entities can likewise contract for energy storage devices to supply frequency responsive reserve, as long as

\(^3\) “5. Increased variable renewable generation will have ... impacts on the efficacy of primary frequency control actions: ... Place[ing] increased requirements on the adequacy of secondary frequency control reserve. The demands placed on slower forms of frequency control, called secondary frequency control reserve, will increase because of more frequent, faster, and/or longer ramps in net system load caused by variable renewable generation. If these ramps exceed the capabilities of secondary reserves, primary frequency control reserve (that is set-aside to respond to the sudden loss of generation) will be used to make up for the shortfall. We recommend greater attention be paid to the impact of variable renewable generation on the interaction between primary and secondary frequency control reserve than has been the case in the past because we believe this is likely to emerge as the most significant frequency-response-based impact of variable renewable generation on reliability.”
applicable terms ensure that either the devices themselves or a partnered resource provide sustained response until frequency is returned to its normal range.

d. Daily resource commitment plans should include considerations to provide frequency responsive reserve throughout the day. In real-time operations, responsible entity operators should monitor their frequency responsive reserve levels in much the same way that Contingency and Regulating Reserve are monitored. To the extent possible, review of and adherence to planned levels and actual performance should be fed back into the commitment planning process to improve both the commitment plan and actual performance. This feedback should be integrated into commitment planning as well as be available to responsible entity operators to monitor levels.

e. If a responsible entity experiences a frequency deviation in conjunction with a Balancing Contingency Event, frequency responsive reserve will normally be restored when Contingency Reserve has been deployed in response to the Balancing Contingency Event. There may at times be circumstances in which this is not the case. The key difference between this and the non-contingent case is whether Contingency Reserve has been deployed. During a Balancing Contingency Event, it may not be possible to restore frequency responsive reserve from previously designated resources until Contingency Reserve has been deployed (a key reason that reserves are additive).

For a non-contingent responsible entity experiencing a frequency deviation due to a Balancing Contingency Event in another Balancing Authority Area, frequency responsive reserve will normally be restored when frequency returns to normal range. There are some exceptions in which this may not be the case. If load is shed (either as contractual resource or for other reasons) and is not restored automatically, the frequency responsive reserve will have served as Contingency Reserve for the contingent responsible entity (even if unintentionally) and frequency responsive reserve for the non-contingent responsible entity will not have been restored. If this is the case, operator action may be needed to restore the frequency responsive reserve by either restoring the load (so that it is again available to be shed) or obtaining it from other available resources.

VI. Capability to Respond to Large Loss-of-Load Events

Because a responsible entity should be able to adjust its resources in such a manner to ensure its ACE recovers in accordance with applicable Reliability Standards, a responsible entity should identify options to respond to large loss-of-load events—that is, the ability to reduce resources or rapidly bring on additional load. In many cases, decommitment of resources is an option, but with this option comes the risk that the decommitted resource cannot be recommitted in a timely manner resulting in the exchange of a current solution for a future reliability problem. Planning can mitigate this problem.

Each responsible entity’s planning for the possibility of a large loss-of-load event should include consideration of (a) its energy import and export schedules with other responsible entities, (b) how large loss-of-load events could be affected by interruption of these schedules, taking into account the terms and conditions under which such energy schedules were arranged, and (c) the
available down range on resources which have been made available by the sale of non-firm energy which may disappear during a Contingency or other Disturbance.

As noted previously, responsible entities should consider developing some form of electronic reserve monitor to track resources available to provide both up and down range of reserves.

VII. Reserve Sharing Groups

Reserve Sharing Groups (RSG) are commercial arrangements among Balancing Authorities to better enable them to collectively meet the requirements of BAL-001-2, BAL-002-2 and BAL-003-1. The spreading of reserve across a larger geographically dispersed group can improve reliability and provides for the opportunity to comply with the BAL performance standards while at the same time economically supplying reserve. However, the RSG should take into account the possibility of delivery being compromised by transmission constraints or generation failures when considering establishing the group’s minimum reserve requirements.

a. Reserve Sharing Group (RSG)

A RSG is a group whose members consist of two or more Balancing Authorities that collectively maintain, allocate, and supply Contingency Reserve to enable each Balancing Authority within the group to recover from Balancing Contingency Events. The NERC Reliability Standard BAL-002-2 allows Balancing Authorities to meet the requirements of the standard through participation in a RSG, which Balancing Authorities have done for many years to increase efficiency and enhance reliability.

Scheduling energy from an Adjacent Balancing Authority to aid recovery need not constitute reserve sharing provided the transaction is ramped in over a period the supplying party could reasonably be expected to load generation in (e.g., ten minutes). If the transaction is ramped in more quickly (e.g., between zero and ten minutes) then, for the purposes of BAL-002-2, the Balancing Authority Areas become a RSG.

The agreement among the participant Balancing Authorities for the RSG should address the minimum reserve requirement for the group, the allocation of reserve among members, and the procedure for activating reserve. In setting its Most Severe Single Contingency (MSSC) or minimum reserve requirements for the group, the RSG should consider how reasonable generation and transmission contingencies may affect the deliverability of Contingency Reserve among the members. The agreement should clearly state each member’s portion of the total reserve requirement as well as the methodology used to calculate the member’s reserve responsibility. The activation and recall of reserve should be defined in detailed terms which should include communication protocols and infrastructure, how long reserve is available, who can call for reserve, and valid reasons for failure to respond to a reserve-sharing request. The agreement also should cover reporting and record keeping for regulatory compliance.

b. Frequency Response Sharing Group
A Frequency Response Sharing Group (FRSG) is a group whose members consist of two or more Balancing Authorities that collectively maintain, allocate, and supply operating resources required to jointly meet the sum of the Frequency Response Obligations of its members.

Frequency Response has many unique characteristics which makes an FRSG different from a RSG. The frequency response capability of individual generating units can change from moment to moment depending on operating point, mode of operation, type of unit, and type of control system. A steam unit which is operating at full valve but not at full capability will have no frequency response even though it appears to have additional capability above its current output. These issues may require responsible entities to develop new unit commitment processes, new operating guidelines, tools for operators, and more consistent governor settings.

The agreement among the participant responsible entities for the FRSG should address the minimum reserve requirement for the group, the allocation of reserve among members, and reporting and record keeping for regulatory compliance. The FRSGs minimum reserve requirement should be conservative to allow for conditions, such as a unit-tripping or transmission contingencies, that could affect members’ ability to supply frequency responsive reserve to each other. The agreement should clearly state each member’s portion of the total reserve requirement as well as the methodology used to calculate the member’s reserve responsibility. Also, the agreement should consider how the information is shared in Real-time based on tools created for the operators.

c. Regulation Reserve Sharing Group

A Regulation Reserve Sharing Group (RRSG) is a group whose members consist of two or more Balancing Authorities that collectively maintain, allocate, and supply the regulating reserve required for all member Balancing Authorities to use in meeting applicable regulating standards.

A RRSG may be used to satisfy the Control Performance Standard (CPS) requirement in BAL-001. Sharing of Regulating Reserve will require real-time data sharing and dynamic transfers between members. The agreement among the participant BAs of the RRSG should contain the maximum amount of regulation to be exchanged and the medium used to communicate the regulation to be shared. The agreement should assign responsibility for arranging transmission service and posting schedules. Regulation magnitudes may at times be limited due to resource availability or transmission constraints, so the RRSG agreement should include mechanisms to provide for such restrictions. If a RRSG has many members, the members may need central data sharing to enable communication in Real-time, as well as more complex definitions of transmission paths among members and mechanisms to address transmission path limitations. Record keeping for the RRSG will primarily be energy schedule records (E-TAGS) and Open

---

4 For a more detailed explanation of the implementation of dynamic transfers in general and for regulation sharing (discussed as supplemental regulation in the document) specifically, see the “Dynamic Transfer Reference Guidelines” reference document in the NERC Operating Manual. This document can be found at http://www.nerc.com/comm/OC/Pages/Operating-Manual.aspx.
Access Same-Time Information System (OASIS) postings that allow energy flow between members. The RRSG agreement should also have mechanisms to settle imbalances and limit the amounts of imbalances between members.

VIII. Operating Reserve Use and Interaction

The responsible entity’s Operating Reserve should include three general categories: frequency responsive reserve, Regulating Reserve and Contingency Reserve. The deployment of these three categories is governed primarily by NERC Reliability Standards.

USE

For all imbalances occurring on its power system, the responsible entity will use its reserve which is addressed by the following four-step process.

**Step 1: Arrest Frequency Change**

The first step in recovery is to arrest the frequency change caused by the imbalance. In most circumstances, this arresting action is performed automatically by the frequency response of generators and load on the Interconnection within the first few seconds of the imbalance. If there is insufficient frequency response or frequency responsive reserve to arrest a frequency decline, the Interconnection frequency will reach underfrequency relay trip points before any of the other steps can be initiated. Frequency response is therefore the most important of the required responses and frequency responsive reserve is the most important of the reserves.

**Step 2: Return Frequency to its Normal Range**

The second step in the recovery process is to return the frequency to its normal range. Again in most circumstances, for small imbalances, this is usually accomplished by applying frequency responsive reserve or Regulating Reserve, and the timeliness of the recovery is governed by the CPS1 portion of BAL-001-2. The timeliness of the recovery from larger imbalances is governed by BAL-002-2, as well as CPS1. For large, sudden imbalances due to loss of generation, this is usually accomplished by applying Contingency Reserve. Current rules in North America require the completion of this step within a fixed time, in most cases 15 minutes. The remainder of the operating reserve not used for the frequency response is available to complete this return to the normal frequency range.

**Step 3: Restore Frequency Responsive Reserve**

The third step in the recovery process is the restoration of the frequency responsive reserve. Restoration of frequency responsive reserve is what indicates the Interconnection is secure and in a position to survive the next imbalance or disturbance. The timeliness of achieving this condition affects the risk that the Interconnection faces.
Step 4: Restore Regulating Reserve or Contingency Reserve

The fourth step is to restore the any Regulating or Contingency Reserve that has been deployed to ensure that the Interconnection can recover from the next imbalance or disturbance within an appropriate time.

Interaction

This four-step process demonstrates that the Operating Reserve components—frequency responsive reserve, Regulating Reserve and Contingency Reserve—do not function in isolation but are always interacting and are often used in conjunction with one another.

The Operating Reserve components can be distinguished from each other by the response time it takes to convert the reserve capacity into deliverable energy. The differences in response time allow the reserves to be utilized from the reserve with the fastest response (frequency responsive reserve) to the reserve with the slowest response time (Contingency Reserve). The deployment of Regulating Reserve in some scenarios can lead to the restoration of frequency responsive reserve. The deployment of Contingency Reserve in some scenarios will assist in the restoration of frequency responsive reserve and Regulating Reserve.

Frequency responsive reserve is a “sub-minute” reserve product. Typically, Regulating Reserve and Contingency Reserve cannot be deployed in the timeframe to assist in keeping frequency above under-frequency relay settings. Regulating Reserve usually does not respond quickly enough to be observable in the Frequency Response Measure (FRM). Contingency Reserve most often takes more than a minute to deploy following the start of the contingency.

Regulating Reserve is often thought of as a “minute plus” reserve product. If it is deployed by any responsible entity in an Interconnection in a direction that supports pushing frequency towards 60 Hz, it will help restore frequency responsive reserve within the Interconnection.

For resource losses, Contingency Reserve activated by the contingent responsible entity often takes a few minutes to begin to be deployed. As its deployment progresses over time and frequency approaches 60 Hz, there will be some restoration of frequency responsive reserve and Regulating Reserve for the contingent responsible entity. Non-contingent responsible entity’s frequency responsive reserve will tend to be restored with the deployment of the contingent responsible entity’s Contingency Reserve as well.

For a responsible entity in a multiple responsible entity Interconnection, it may coincidentally need to deploy frequency responsive reserve for a load greater than generation imbalance within its Interconnection at the same time that it needs to deploy its Regulating Reserve in the upward direction. It may also experience its MSSC requiring the deployment of Contingency Reserve while the need for frequency responsive reserve and Regulating Reserve are at a maximum. The responsible entity should plan its reserve allocations to be compliant with the NERC Reliability Standards in such a coincidental scenario.

Interconnections with only one responsible entity are unique in that only they can correct their system frequency. Frequency responsive reserve will always be deployed automatically and coincidentally when Contingency Reserve needs to be deployed for a large contingency. In a single
responsible entity Interconnection, frequency responsive reserve and Contingency Reserve are inherently co-mingled, and together they must at least equal MSSC. As with a multiple responsible entity Interconnection, Regulating Reserve needs to be separate from frequency responsive reserve and Contingency Reserve.

There is an additional characteristic of reserve enabling the reserve categories to be ordered. Operating Reserve categories are partially substitutable for one another. Frequency responsive reserve is the only type of reserve that could be used as the exclusive reserve that would enable an Interconnection to operate reliably. Attempts to operate an Interconnection without frequency responsive reserve would result eventually in the activation of frequency relays. As long as the amount of frequency responsive reserve available is greater than the energy imbalance on the Interconnection, the Interconnection will remain reliable.

The difficulty with operating an Interconnection with only frequency responsive reserve is that frequency responsive reserve is limited in the total amount available. Frequency responsive reserve will arrest the frequency change but will not restore frequency to its normal range, leaving the Interconnection vulnerable to the next contingency. The frequency responsive reserve provided by load damping is limited and the additional frequency responsive reserve provided by governor response is relatively expensive to provide in large quantities.

Regulating Reserve is a reserve that can be substituted on a limited basis for frequency responsive reserve. When Regulating Reserve is substituted for frequency responsive reserve, the Regulating Reserve restores the frequency responsive reserve by replacing it with dispatched energy. As frequency is returned to normal range the frequency responsive reserve is restored and available for reuse. The amount of Regulating Reserve that can be substituted for Frequency Response is determined by the difference between, (1) the frequency responsive reserve required to manage the largest imbalance that could occur on the Interconnection, and (2) the frequency responsive reserve that could be required in a period shorter than the response time for Regulating Reserve. This ensures there is sufficient frequency responsive reserve available to manage any imbalance occurring before there is time to replace the frequency responsive reserve being used with Regulating Reserve. Also it extends the effective amount of frequency responsive reserve available, allowing the Interconnection to operate with less governor response because the amount of load damping is not easily modified.

In all cases, the minimum frequency responsive reserve required, when only frequency responsive reserve and Regulating Reserve are available, is determined by the maximum imbalance that cannot be managed by supplementing frequency responsive reserve with Regulating Reserve. In addition, the sum of the frequency responsive reserve and Regulating Reserve should exceed the largest energy imbalance occurring on the Interconnection. Thus, when substituting Regulating Reserve for frequency responsive reserve the total amount of the frequency responsive reserve and Regulating Reserve should be equal to or exceed the amount of frequency responsive reserve when it is used alone.

Regulating Reserve and frequency responsive reserve can be further supplemented with Contingency Reserve. Contingency Reserve can be manually dispatched to restore any frequency responsive reserve currently being used to respond to declining frequency. When dispatched, it
restores both frequency responsive reserve and Regulating Reserve making them available for reuse. Therefore, Contingency Reserve can be substituted for a portion of the Regulating Reserve that could be substituted for frequency responsive reserve. When this substitution is implemented, the sum of the frequency responsive reserve, Regulating Reserve and Contingency Reserve should exceed the sum of Regulating Reserve and frequency responsive reserve if Contingency Reserve is not used.

This illustrates a power system that uses many levels of substitution to improve economic efficiency and reliability. Regulating Reserve is substituted for frequency responsive reserve as determined by reliability needs; Contingency Reserve is substituted for Regulating Reserve as determined by reliability needs. Reliability limits for these substitutions can be quantified with a set of inequalities:

\[
\begin{align*}
FRR + RRO & \geq FRRO & \text{Inequality (1)} \\
FRR + RR + CR & \geq FRR + RRO & \text{Inequality (2)}
\end{align*}
\]

- \( FRR + RRO \geq FRRO \) 
  - Frequency response obligation (FRO), equal to MW of frequency responsive reserve (FRR) when only FRR is used.

- \( FRR + RR + CR \geq FRR + RRO \) 
  - MW of FRR when another service is substituted for FRR.

- \( RRO = MW \text{ of Regulating Reserve (RR) when nothing is substituted for RR.} \)

- \( RR = MW \text{ of RR when another service is substituted for RR.} \)

- \( CR = MW \text{ of CR when nothing is substituted for CR.} \)

Both inequalities represent the total required reserve on both sides of the inequality.

This is the basis used to determine the Frequency Response Obligation in BAL-003-1 as adjusted by the base frequency error profile resulting from reserve substitution. In addition, the Contingency Reserve Requirement in R2 of BAL-002 determines the minimum CR when it is not in use for recovery but it does not require that the reserve used to meet the requirement exclude frequency responsive reserve or Regulating Reserve. Since Regulating Reserve is unique to each responsible entity and can be determined only by evaluating the characteristics of their load and generation resources, a minimum Regulating Reserve Obligation is not specified in BAL-001. The variations of substitution of reserve as shown above suggests that the best test for reserve adequacy is whether the total capability of resources designated to provide Regulating Reserve, Contingency Reserve, and frequency responsive reserve is at least equal to the amount required to meet all reserve requirements concurrently.

Additionally, this indicates that during the deployment of reserve in real-time, there are only limited ways to determine whether a responsible entity is holding adequate reserve. This determination can only be based on a prospective look during operations planning when there are no deviations from the expected deployment of reserve. Because this is the case, also it is important for the responsible entity to have a feedback mechanism included in its evaluations of reserve to include the uncertainties experienced during actual reserve usage. This could be accomplished with a reserve monitoring tool.
The calculation of reserve levels including frequency responsive reserve, Regulating Reserve and Contingency Reserve begins with the calculation of the amount of each type of reserve available from each resource providing any of these three types of Operating Reserve. Once the individual resource reserve contributions have been calculated, the responsible entity’s total reserves by category can be determined by the sum of the reserve contributions for all contributing resources.

This type of calculation for these three types of reserves (frequency responsive reserve, Regulating Reserve and Contingency Reserve) is not supported in many current EMSs because the calculation of frequency responsive reserve and the interaction between reserves requires additional data not currently maintained in many EMSs. Additional data required to support the frequency responsive reserve calculation includes, but is not limited to, unit droop and dead-band settings and Interconnection Underfrequency Load Shedding (UFLS) frequency limits. Additional data may be required for other types of resources.

Finally, any calculation of the total amount of reserve and the amount in each category can change with a change in output/use of any of the resources providing reserve for the responsible entity. For example, dispatch of Contingency Reserve from a resource could also affect the frequency responsive reserve or Regulating Reserve that is available from that same resource by moving the operating point of the resource nearer to one of the resource’s operating limits. This could result in a reduction of one of the other reserve types in addition to the reduction in the amount of Contingency Reserve resulting from the dispatch. This dynamic reserve interaction should be included in operations planning and the tools used to provide the System Operator with the best information.

Related Documents and Links:

NERC Operating Committee Charter

NERC Critical Infrastructure Charter

NERC Planning Committee Charter
http://www.nerc.com/docs/pc/Board%20Approved%20PC%20Charter%20August%202011.pdf

NERC Operating Manual

Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation, Key Findings
Lawrence Berkeley National Laboratory
### Revision History:

<table>
<thead>
<tr>
<th>Date</th>
<th>Version Number</th>
<th>Reason/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBD</td>
<td>1.0</td>
<td>Initial Version – “Operating Reserve Management”</td>
</tr>
</tbody>
</table>