Reliability Guideline

Operating Reserve Management: Version 3

Preamble

It is in the public interest for NERC to develop guidelines that are useful for maintaining and enhancing the reliability of the Bulk Electric System (BES). The subgroups of the Reliability and Security Technical Committee (RSTC)—in accordance with the RSTC charter[1] are authorized by the NERC Board of Trustees to develop reliability and security guidelines. 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 NERC Reliability Standards are monitored or enforced. While the incorporation, of guideline practices, is 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 (RSGs), regulation RSGs, 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.

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 leads 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.

[1] https://www.nerc.com/comm/RSTC/RelatedFiles/RSTC_Charter_approved20191105.pdf

Assumptions

- There can be a variety of methods that responsible entities use to ensure that sufficient Operating Reserves are available to deploy in order to support reliability. This guideline does not specify or prescribe how the need for sufficient operating reserves are met.
- NERC, as the FERC certified ERO, 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.
- Each registered entity in the NERC compliance registry is responsible and accountable for maintaining reliability and compliance with the mandatory NERC Reliability Standards to maintain the reliability of the BES.
- This guideline is not intended to supersede any NERC Reliability Standards or Regional Specific Reliability Standards. Its intent is to provide a general overview to its readers of the concepts of Operating Reserve Management.
- 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.

Background

There is often confusion when operators and planners talk about reserves. One major reason for misunderstanding is a lack of common definitions; NERC's definitions have changed over time. In addition, most NERC Regional Entities (REs) developed their own definitions. Capacity obligations have historically been the purview of state and provincial regulatory bodies, meaning that there are many different expectations and obligations across North America.

The second area of confusion concerning reserves deals with the limitations of each BA's energy management system (EMS). Common problems include the following:

- Counting all "headroom" of on-line units as spinning reserve even though it may not be available in 10 minutes (i.e., lag from adding mills or fan speed changes)
- No intelligence in the EMS regarding load management resources
- No corrections for "temperature sensitive" resources, such as natural gas turbines
- Inadequate information on resource limitations and restrictions
- Reserves that may exist and are deployed outside the purview of the EMS system

Definitions

When reading this Reliability Guideline, the reader should note that all terms contained in the NERC Glossary of Terms and used in this Guideline are capitalized. In addition to those terms some additional terms have been defined and provided below to assist the reader. Terms defined in Italics below distinguish them from those defined and approved by NERC.

Bottoming Out Condition: A situation experienced by a BA where the Balancing Authority Area load is at or below the minimum unit capabilities of online units. This situation results in the BA having no regulation down to support operations and further load reductions. Also known as a min gen condition.

Contingency Reserve: This is the provision of capacity deployed by the BA to respond to a balancing contingency event and other contingency requirements, such as Energy Emergency Alerts (EEAs) as specified in the associated NERC Reliability Standards.

Contingency Event Recovery Period: A period that begins at the time that the resource output begins to decline within the first one-minute interval of a Reportable Balancing Contingency Event and extends for fifteen minutes thereafter.

Contingency Reserve Restoration Period: A period not exceeding 90 minutes following the end of the Contingency Event Recovery Period.

Frequency-Responsive Reserve (FRR): On-line generation with headroom that has been tested and verified to be capable of providing droop as described in the *Primary Frequency Control Reliability Guideline Reliability Guideline.*[2] Variable load that mirrors governor droop and dead-band may also be considered FRR.

Interruptible Load/Demand: Demand that the end-use customer makes available to its load-serving entity via contract or agreement for curtailment. Note: If the load can be interrupted within 10 minutes, it may be included in Contingency Reserve; otherwise, this load is generally included in Operating Reserves - Supplemental.

Most Severe Single Contingency (MSSC): The Balancing Contingency Event, due to a single contingency that was identified using system models maintained within the RSG or a BA's area that is not part of an RSG, that would result in the greatest loss (measured in megawatt (MW) of resource output used by the RSG or a BA that is not participating as a member of an RSG at the time of the event to meet firm demand and export obligation (excluding export obligation for which contingency reserve obligations are being met by the sink BA).

Operating Reserve: Operating reserve is the capability above firm system demand required to provide for regulation, load forecasting error, equipment forced and scheduled outages, and local area protection. It consists of spinning and non-spinning reserve.

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[2] https://www.nerc.com/comm/OC_Reliability_Guidelines_DL/PFC_Reliability_Guideline_rev20190501_v2_final.pdf

Operating Reserve–Spinning: This includes generation synchronized to the system and fully available to serve load within the Disturbance Recovery Period following the contingency event or load fully removable from the system within the Disturbance Recovery Period following the contingency event deployable in 10 minutes.

Operating Reserve–Supplemental: This includes generation (synchronized or capable of being synchronized to the system) that is fully available to serve load within the disturbance recovery period following the contingency event or load fully removable from the system within the disturbance recovery period following the contingency event that can be removed from the system within 10 minutes.

Other Reserve Resources**:** This includes resources that can be used outside the continuum of Operation Reserves *Figure: 1* (e.g. on four hours' notice, generations that cannot be started within 90 minutes, preplanned demand response resources).

Planning Reserve: This is the difference between a BA's expected annual peak capability and its expected annual peak demand expressed as a percentage of the annual peak demand.

Projected Operating Reserve**:** This includes resources expected to be deployed for the point in time in question.

Regulating Reserve: This is an amount of Operating Reserve – Spinning that is responsive to automatic generation control (AGC) sufficient to provide normal regulating margin.

Replacement Reserve: Resources used to replace designated Contingency Reserve that have been deployed to respond to a contingency event. Each NERC RE sets times for Contingency Reserve restoration, typically in the 60–90-minute range. The NERC default Contingency Reserve restoration period is 90 minutes after the Contingency Event Recovery Period.

Supplemental Reserve Service**:** Supplemental reserve service provides additional capacity from electricity generators that can be used to respond to a contingency within a short period, usually 10 minutes. This is an ancillary service identified in FERC Order 888 as necessary to affect a transfer of electricity between purchasing and selling entities and is effectively FERC's equivalent to NERC's Operating Reserve.

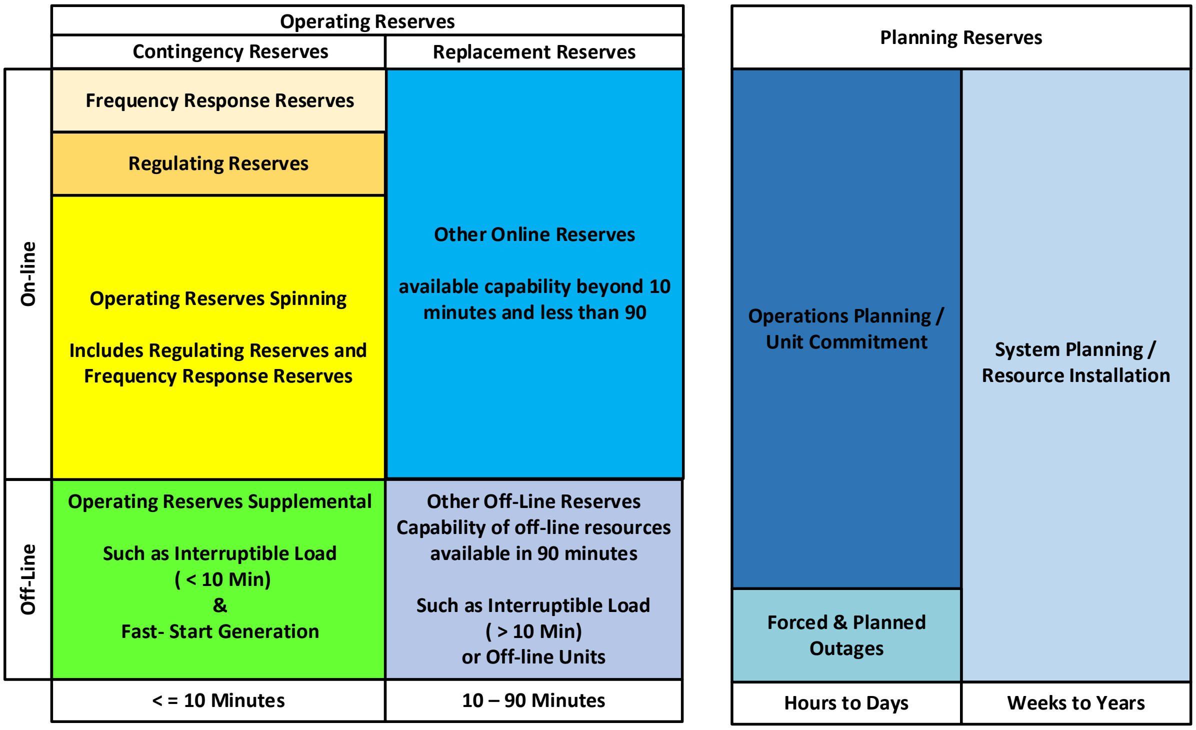

Figure 1.1: Operating Reserves

The various terms associated with this guideline document represent distinct conditions pertaining to reserve management and assessment. Figure 1 clearly shows the differing types of reserves between the operating and planning environment and potential availability based on time or generating unit operational status.

Guideline Details

An effective Operating Reserve program should address the following components:

- Management roles and expectation
- System operator roles
- Regulating reserve
- Contingency reserve
- Frequency responsive reserve
- Capability to respond to large loss-of-load events
- Reserve sharing groups
- Operating reserve interaction
- Load forecast error
- Fuel constraints

- Deliverability of reserves
- Unit commitment

Each individual component should address safety; processes and procedures; evaluation of any issues or problems along with solutions; testing; training; and communications. These provisions and activities together should be understood to be an Operating Reserve program.

Each responsible entity should evaluate the total reserve needed to meet its obligations under NERC Reliability Standards, namely frequency response reserves, regulating reserves up, regulating reserves down, contingency reserves, and operating reserves. Given that 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 BA's area control error (ACE) in either direction in response to each of the following:

- Frequency deviations
- Bottoming out conditions
- Ramping requirements
- A Balancing Contingency Event
- Events associated with EEA 2[3]
- Events associated with EEA 3[4]
- A large loss-of-load event

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:

- Set expectations for safety, reliability, and operational performance
- Assure that an Operating Reserve program exists for each responsible entity and is current
- Provide periodic training on the Operating Reserve program and its purpose and requirements
- Ensure the proper expectation of Operating Reserve program performance
- Share insights across industry associations
- Conduct periodic evaluations of the effectiveness of the Operating Reserve program considering feedback from participants and incorporating lessons learned

[3] https://www.nerc.com/EOP-011-1.pdf

System Operator Roles

BA Operator

It is important for the system operator to know the specifics of their BA reserve strategy and maintain situation awareness through the following:

- Participate in appropriate system operator training that includes BA reserves management
- Ensure the Operating Reserve information is always current
- Maintain situation awareness and projection of reserves for a 2-hour to 6-hour horizon
- Review and validate reserve plan while considering load forecast, unit commitment, fuel supply, weather conditions, and reserve requirements
- Implement the BA Operating Reserve program in real-time that should
  - Ensure adequate reserves are available to address loss of MSSC or Frequency deviations in real-time
  - Coordinate communications with RC if inadequate reserves are forecasted or experienced
  - Adhere to EOP Operating Standards
  - Ensure the proper EEA is called when a reserve short fall is forecasted or experienced

RC Operator

It is important for the system operator to look at other indicators to determine the ultimate course of action, such as the following:

- Is the BA or BAs' ACE predominantly negative for an extended period?
- Is frequency low (i.e., more than 0.03 Hz below scheduled frequency)?
- Are reserves low in multiple BAs?
- Is load trending upward or higher than anticipated?

Based on the duration and severity of the situation, action steps may include the following:

- Verify reserve levels
- Follow EEA–review and understand individual BA EEA plans
- Direct BA(s) to take action to restore reserves
- Direct the identification of load to shed to withstand the next contingency for a post contingent action.
- Redistribute reserves by requesting BA to redispatch units to hold reserves in different areas of the BA footprint

- Shed load where appropriate if the BA or Transmission Operator cannot withstand the next contingency

Regulating Reserve

The responsible entity's balance between demand, supply (generation minus metered interchange) and frequency support is measured by its ACE. Because changes in supply and demand cannot be predicted precisely, there will be a mismatch between them, resulting in a nonzero ACE.

Each responsible entity should have a documented regulating reserve process that ensures that the responsible entity has sufficient capacity to meet the performance requirements of BAL-001. The responsible entity's process should include the following at a minimum:

- **A method for determining its regulating needs**: This method should consider the entity's generation mix, type of load, the variability in both generation and load, and the probability of extreme influences (e.g., weather).
- **Knowing what 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.
- **The incorporation of contractual arrangements into regulating needs, 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
- **Evaluation of its planned regulating reserve needs over the operating time horizon and gauge its ability to meet its regulating reserve needs on at least an hourly basis:** This should be based on changing system conditions, such as the current load, forecast errors, and generation mix.
- **Planning and implementation of the ability to restore its regulating reserve as needed:** This may include the ability to restore regulating reserve in either direction.
- **Ensuring that the regulating reserve is used by only one entity:** The regulating reserve process should include a method whereby its regulating reserve is not included in another responsible entity's Operating Reserve (i.e. regulating, contingency, or FRR) policy.

Contingency Reserve

When a responsible entity experiences an event (i.e., loss of supply or significant scheduling problems that 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 NERC Reliability Standards.
For a responsible entity to meet the requirements of the NERC Reliability Standards BAL-002, the BA needs to identify its MSSC to determine its base contingency reserve. Because there is no forgiveness for this minimum amount of contingency reserve not deployed when called upon, the individual entity could consider additional amounts based on risk analyses. To be effective, contingency reserves should be able to be deployed (including activation or communication needs) to meet the contingency event recovery period for balancing contingency events. Reserve amounts set aside as frequency responsive include unit governor reserves. These local unit governor responses are independent of control center control. A unit

may or may not be able to provide frequency reserves or contingency reserves if operating at maximum output. If the unit is not operating at maximum output, the unit should be capable of providing frequency response. Due to the interactions of frequency reserves, these frequency reserves are included in the available minimum contingency reserve amounts in Interconnections composed of more than one responsible entity. At any given time, a unit may instead be loaded to maximum output and, if so, unavailable to participate in frequency response and contingency reserves.

Additionally, the responsible entity should consider an appropriate mix and coordination of FRR and contingency reserve to ensure that the responsible entity has the ability to respond to frequency events on the Interconnection as well as in its own BA area in accordance with all NERC and RE reliability standards.

Various resources may be considered for use as contingency reserve provided, they can be deployed within the appropriate time frame. As technology and innovations occur, this list may continue to grow and may include the following:

- Unloaded/loaded generation, such as quick start CTs, hydro facilities, portions of unit ramping capabilities
- Off-line generation
- Demand resources
- Energy storage devices
- Resources like wind, solar, etc., provided that any limitations are considered
- Hybrid Facilities – (e.g. Solar/Battery)

Responsible entities should consider how schedule interruption would affect their Contingency Reserves while considering 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.

For RSGs, there is a prohibition against counting toward the responsible entity’s Contingency Reserve any capacity that is already included in another responsible entity’s regulating, contingency, or FRR policy. Special coordination between RSG members may be required for resources dynamically transferred between multiple responsible entities.

To assure a responsible entity can respond to a balancing contingency event in real-time, the responsible entity should plan for its available Contingency Reserves for the operating time horizon (i.e. operations planning, same day and real-time operations). The BA operator should focus their situation awareness and evaluation of reserves in a time horizon between next hour and multiple days out. The review should be flexible so that it can be updated to reflect changes available generation, load forecast, the amount of reserve available, or the amount of reserve required.

Responsible entities should consider developing some form of electronic reserve monitor that would track resources available to provide the necessary response and the amount of capacity each could provide. Many EMSs 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 that have been made available by the purchase or sale of non-firm energy that may disappear during an event.
Responsible entities should consider leveraging their Replacement Reserves to meet the Contingency Reserve Restoration Period, preplanning, and training of system operators may be required. Actions like the following should be considered:

- Verification of status/availability of additional resources
- Commitment of additional resources
- Implementation of demand resources, such as interruptible loads (usually prearranged contractually)
- Curtailment of recallable transactions
- The effect of emergency schedules that end before recovery completion

The responsible entity should exercise prudent operating judgment in distributing Contingency Reserves, considering the effective use of capacity in an emergency, the time required to be effective, transmission limitations, and local area requirements.

Frequency Responsive Reserve

Each responsible entity should maintain an amount of resources available to respond to frequency deviations. Planned FRR (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, FRR 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., inverter based resources, controllable load contracted for that purpose, certain energy storage devices) 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 FRR process ensuring the responsible entity has sufficient capacity to meet the performance requirements of BAL-003. The process should include at least the following:

- The BAL-003 standard, *Frequency Response and Frequency Bias Setting*[4], 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) FRR level (in MW) for a given responsible entity, multiply 10 times the

[4] http://www.nerc.com/pa/Stand/Reliability%20Standards/BAL-003-2.pdf

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 is as follows:

- Given: ABC responsible entity is in the Eastern Interconnection and its pro-rata portion of IFRO is 1.5%.
- Currently, the key Eastern Interconnection parameters from are: IFRO = 1015 MW/0.1 Hz and MDF = 0.420 Hz. The responsible entity's FRO is {1.5% *1015 MW/0.1 Hz} or 15.2 MW/0.1 Hz.
- The responsible entity's initial FRR target is {10 * 15.2 * 0.420} or 63.84MW.
- The initial target may need to be modified based on several factors. 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 FRR that assures compliance at an acceptable cost.

- 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 FRR; 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. It is prudent practice to evaluate and test units periodically. Therefore, any resource that participates in frequency response reserve should be evaluated periodically to ensure the expected response (e.g. NERC Generator Owner/Operator Survey, or internal evaluation). Moreover, the responsible entity should have an appropriate mix of both primary and secondary reserves. The Lawrence Berkeley National Laboratory report highlights this: *Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation, Key Findings*.[5]
- As long as the total FRR amounts for each responsible entity are satisfied, any amount of FRR 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 demand side options that respond to frequency deviations (usually at preset thresholds) to provide FRR. Responsible entities can likewise contract for energy storage devices to supply FRR as long as applicable terms ensure that either the devices themselves or a partnered resource provide sustained response until frequency is returned to its normal range.
- Daily resource commitment plans should include considerations to provide FRR throughout the day. In real-time operations, responsible entity operators should monitor their FRR levels in much the same way that contingency and regulating reserve are monitored. To the greatest possible extent

[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."
https://www.ferc.gov/sites/default/files/2020-05/frequencyresponsemetrics-report.pdf

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.

- If a responsible entity experiences a frequency deviation in conjunction with a balancing contingency event, FRR will normally be restored when Contingency Reserves have been deployed in response to the balancing contingency event, but there may be circumstances when this is not the case. The key difference between this and the noncontingent case is whether Contingency Reserves have been deployed. During a balancing contingency event, it may not be possible to restore FRR from previously designated resources until Contingency Reserves have 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 BA area, FRR will normally be restored when frequency returns to its normal range, but there are some exceptions where this may not be the case. If load is shed (either as a contractual resource or for other reasons) and is not restored automatically, the FRR will have served as Contingency Reserves for the contingent responsible entity (even if unintentionally) and FRR for the noncontingent responsible entity will not have been restored. If this is the case, operator action may be needed to restore the FRR by either restoring the load so that it is again available to be shed or obtaining it from other available resources.

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 NERC Reliability Standards, a responsible entity should identify options to respond to large loss-of-load events, meaning 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 its energy import and export schedules with other responsible entities; how large loss-of-load events could be affected by interruption of these schedules while taking into account the terms and conditions under which such energy schedules were arranged; and the available down range on resources that have been made available by the sale of non-firm energy that 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.

Reserve Sharing Groups

RSGs are commercial arrangements among BAs to better enable them to collectively meet the requirements of BAL-001, BAL-002, and BAL-003. 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.

An RSG is a group whose members consist of two or more BAs that collectively maintain, allocate, and supply Contingency Reserves to enable each BA within the group to recover from balancing contingency events. The NERC Reliability Standard BAL-002 allows BAs to meet the requirements of the standard through participation in an RSG, something BAs have done for many years to increase efficiency and enhance reliability. The primary benefit of RSGs is that they reduce the capacity a BA is required to withhold for reserves. This can be especially impactful for smaller BAs that have a large generator within their boundaries. Without RSGs, some smaller BAs could be required to withhold 20% or more of their capacity just for Contingency Reserves in addition to all the other reserves they carry.

Compliance for an RSG is measured via monitoring individual and group performance. The RSG can meet the compliance obligations of an event if all members individually pass based upon individual ACE values. If each member of the RSG demonstrates recovery by returning its Reporting ACE to the least of the recovery value of zero or its pre-reporting contingency event ACE value, the NERC compliance requirement is met. In addition, the RSG can also meet the compliance obligation if the collective ACE or sum of the ACE demonstrates recovery by returning the RSG's reporting ACE to the least of the recovery value of zero or its pre-reporting contingency event ACE value. An RSG can meet compliance via either method.

In order for an event to be an RSG event, the contingent BA normally has to call on reserves from the group. If it does not, then the BA is standing alone for that event. Some agreements can require that all events are RSG events by rule. Based on the agreements of the RSG, some BAs in an RSG will not have a single contingency that is a reportable event; the only possible way for them to cause a reportable event is with multiple contingencies all occurring within the 60-second period as defined in the Balancing Contingency Event glossary Term. For example, losing an entire generating station due to a fault that clears the bus.

The agreement among the participant BAs for the RSG should address the following:

- The minimum reserve requirement for the group
- The allocation of reserve among members
- The procedure for activating reserve in detailed terms that should include communication protocols and infrastructure, how long reserve is available, and who can call for reserve
- The method of establishing its MSSC or minimum reserve requirements for the group
- How the BAs will manage shortages in reserves and capacity

- The criteria used to determine when a member must declare an EEA
- The criteria that allow members to aid a deficient entity through the RSG by allowing BAs to contribute additional reserves to the group
- How generation and transmission contingencies may affect the deliverability of Contingency Reserves among the members
- Each member's portion of the total reserve requirement
- The methodology used to calculate the member's reserve responsibility
- Identification of valid reasons for failure to respond to a reserve-sharing request
- The reporting and record keeping for regulatory compliance

Scheduling energy from an adjacent BA 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., 10 minutes). For certain RSG arrangements, if the transaction is ramped in more quickly (e.g., between 0 and 10 minutes) then, for the purposes of BAL-002, the BA areas are considered to be an RSG.
RSGs typically flow on transmission reliability margin (TRM) and have an annual deliverability study done by all the respective transmission planners. Some BAs may have to carry a disproportionate share of reserve if some of their large units are not completely deliverable. These issues may require a special operating guide for local congestion management.

Frequency Response Sharing Group

As defined by NERC, a frequency response sharing group (FRSG) is a group whose members consist of two or more BAs that collectively maintain, allocate, and supply operating resources required to jointly meet the sum of the FRO of its members.

Frequency response has many unique characteristics that make an FRSG different from an 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 that 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 one or more of the following:

- New unit commitment processes
- New operating guidelines
- Additional tools for operators
- 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 FRR 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.

NERC Reliability Standard BAL-003 allows BAs to meet their FROs by electing to form FRSGs. Attachment A of that same standard specifies that an FRSG may calculate their frequency response measure (FRM) performance in one of two ways; calculate a group NIA or aggregate the group response to all events in the reporting year as one of the two following options:

- Single FRS Form 2 utilizing a group NI_A for each event and an accompanying FRS form 1 for the FRSG
- A summary spreadsheet that contains the sum of each participant's individual event performance and an accompanying FRS Form 1 for the FRSG

This section of the guideline is intended to provide recommended practices to consider for BAs when performing the following actions:

- Establishing FRSGs
- Calculating FRSG FRM performance

The Generator Governor Frequency Response Advisory[6] issued notice to industry on the importance of resource configurations for governors and control systems to allow for the provision of primary frequency response. Subsequently, a specific description of practices necessary for resources to provide primary frequency control, including the coordination of turbine controls with plant outer loop controls and an explanation of the different components of frequency response, can be found in the *Primary Frequency Control Reliability Guideline*[7].

Existing BAL-003 Forms 1 and 2 provide short-term bilateral transactions of frequency response and do not require the formal establishment and registration of a long-term FRSG, so these arrangements are not addressed by this guideline. This section of the guideline focuses solely on establishment and operating practice guidelines for a multiparty FRSG.

Establishment/Structure of an FRSG

Certain minimum criteria should apply to all candidate FRSGs prior to registration and establishment. FRSG registration is necessary to provide ERO staff with sufficient information to modify the FRSG's FRO for each operating year. The FRSG FRO is the aggregate of member BAs' FROs, including the information in the

[6] https://www.nerc.com/pa/rrm/bpsa/Alerts%20DL/2015%20Alerts/NERC%20Alert%20A-2015-02-05-01%20Generator%20Governor%20Frequency%20Response.pdf
[7] https://www.nerc.com/comm/OC/RS_GOP_Survey_DL/PFC_Reliability_Guideline_rev20190501_v2_final.pdf

tables used in Form 1, and determine unique FRSG codes (substitutes for the BA codes normally used) for use in summary Form 1.

An FRSG should have a formal agreement among its members in place prior to registration. Depending on the structure and characteristics of the member BAs, the FRSG agreement among the participant responsible entities for the FRSG may need to address the following:

- Minimum frequency-responsive reserve requirement for the group
- Each member's portion of the total frequency-responsive reserve requirement
- Requirements, if applicable, of specific resources to provide frequency response
- Members' reporting, record keeping, and accountability for regulatory compliance
- Provisions for each member's alternative minimum frequency-responsive reserve requirements in identified areas in the event of emergency scenarios, such as an islanding event
- Methodology used to calculate the member's frequency-responsive reserve responsibility
- How information is shared among members in real-time
- Tools for operators to have situational awareness of frequency-responsive reserves of the FRSG
- When and how to bring more frequency-responsive reserves to bear (e.g. conservative operations, periods of low inertia)

FRSGs must be pre-arranged and member participation must coincide with the BAL-003 operating year (i.e., December 1 through November 30 of the following year). Any member of the BA's minimum period of participation must be one BAL-003 operational year. Partial BAL-003 operating year participation is not allowed. Per-event participation with other BAs is a bilateral transaction and is not considered a formation of an FRSG. Like bilateral transactions, FRSGs can only be established prior to the analysis period, and no BA may be a member of more than one FRSG at any given time.

All FRSG member BAs must be in the same Interconnection. An FRSG can be noncontiguous, but each FRSG may be subject to a transmission security review by potentially affected BAs and Transmission Operators. In some cases, a transmission security review by potentially affected BAs and Transmission Operators may be necessary for contiguous FRSGs if, for example, parallel flows caused by individual members' responses may impact other BAs or Transmission Operators.

Operations of a FRSG

FRSGs and their constituent BAs should attempt to fully respond to each event in the BAL-003 operating year.

FRSG who calculate an FRSG NI_A, should properly time-align tie line data to account for data latency and difference in member BAs' EMS scan rates. To the extent possible, this adjustment should be reflected in real-time data provided to operators. The adjustment times for each alignment should be reviewed at least annually to determine if a different amount of adjustment is needed.

The FRSGs minimum frequency-responsive 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.

Although an explicit frequency-responsive reserve requirement is not necessary in every case, the FRSG should account for frequency-responsive reserves among its members in real-time. Members of an FRSG should consider including such provisions in their organizational documents.

Analysis/Reporting

FRSG member BAs must select an entity to report summary information for the FRSG to NERC. As noted above, FRSG reporting is done according to Attachment A in BAL-003.

For tie line data not already time-aligned, the FRSG and its member BAs should properly time-align prior to completing the aggregate FRS Form 2s to account for data latency and difference in member BAs' EMS scan rates.

Changes to Form 1 necessary to allow use of appropriate adjustments of FRM will be referred to NERC staff for development and implementation and those changes will be routed through the appropriate NERC committees for any vetting/validation needed.

Regulation Reserve Sharing Group

A regulation RSG is a group whose members consist of two or more BAs that collectively maintain, allocate, and supply the regulating reserve required for all member BAs to use in meeting applicable regulating standards.

A regulation RSG 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[8] between members. The agreement among the participant BAs of the regulation RSG 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 regulation RSG agreement should include mechanisms to provide for such restrictions. If a regulation RSG 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 regulation RSG will primarily be energy schedule records (E-Tags) and Open Access Same-Time Information System postings that allow energy flow between members. The regulation RSG agreement should also have mechanisms to settle imbalances and limit the amounts of imbalances between members.

[8] 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. This document can be found at https://www.nerc.com/comm/OC/ReferenceDocumentsDL/Dynamic_Transfer_Reference_Document_v4.pdf

Operating Reserve Interaction

The responsible entity's Operating Reserves definition should include three general categories: FRR, regulating reserve, and contingency reserve. NERC Reliability Standards primarily govern the deployment of these three categories.

Load Forecast Error

The BA Operating Reserve projections should consider load forecast error when establishing reserve levels. The following is a list of considerations that may be evaluated. These may change from day to day, from season to season, and should be included in the commitment of resources.

- Weather forecast
- Seasonal temperature variations
- Model error
- Speed of weather event

Fuel Constraints

Once resources are identified, a second review should consider fuel constraints to determine if any limitations generation exist. The following is a list of considerations that may be evaluated. These may change from day to day, from season to season, and should be included as part of a BA's projection of operating reserves and contingency reserves.

- Delivery Limitations such as Operational Flow Orders – (OFOs)
- Availability of fuel (e.g. weather impacts, market, ability to purchase)
- Transportation considerations
- Fuel supply (e.g. size of coal pile, amount of fuel oil, water reserves)
- Variability (e.g. solar and wind)
- Energy Storage Resources
  - Energy Storage Duration
  - State of Charge

Deliverability of Reserves

Deliverability of reserves is an important consideration. If reserves are undeliverable across the BA, then the BA is at increased risk of not complying with BAL-002. As transmission outages occur, the ability to deliver energy across the BA changes. A BA should consider any restrictions or limitations that may reduce generation capability as part of their operating and contingency reserve projections. The following may impact the deliverability of reserves:

- Transmission availability
- Transmission constraints

- Shape/size of BA
- RSG Considerations –
    - Ability to deliver with available transmission
    - Connection through an intermediate member
    - Operating procedures

Unit Commitment

When developing plans and addressing the needs of a BA or an RSG to reliably meet the demands of customers, unit commitment is a key component of successfully planning and ensuring that the needed generation is available in real-time operations. When dispatching the system, the BA operator should coordinate and consider any impacts to operating reserves and contingency reserves. The following is a list of considerations that may be included in the unit commitment process:

- Unit start-up time
- Available personnel
- Maintenance activities
- Environmental limitations:
    - Drought constraints
    - Intake constraints
    - Weather Conditions (Temperatures, cloud coverage, wind speeds, precipitation and humidity)
- Hydrothermal limitations
- Battery Management
- Fuel Supply
- Renewable Forecast Error

For all imbalances occurring on its power system, the responsible entity will use its reserve that 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 FRR 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 FRR is the most important of the reserves.

Step 2: Contingency Reserve Deployment- Returning Frequency to its Normal Range

The second step in the recovery process is to return the frequency to its normal range. Again, this is usually accomplished by applying FRR or regulating reserve in most circumstances for small imbalances, and the CPS1 portion of BAL-001 governs the timeliness of the aggregate of such recoveries. The timeliness of the recovery from larger imbalances is governed by BAL-002 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, 15 minutes in most cases. 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 FRR. Restoration of FRR 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: Operating Reserves Conversion–Restoring Regulating Reserve or Contingency Reserve

The fourth step is to restore any Regulating or Contingency Reserves 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 (i.e. FRR, regulating reserve and contingency reserve) are used in conjunction with one another, do not function in isolation, are always interacting, and often overlap due to timing requirements.

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 (i.e. FRR) to the reserve with the slowest response time (i.e., Contingency Reserve). The deployment of regulating reserve in some scenarios can lead to the restoration of FRR. The deployment of Contingency Reserve in some scenarios will assist in the restoration of FRR and regulating reserve.

FRR is a “sub-minute” reserve product, and governor response provides it in most cases. Typically, Regulating Reserves and Contingency Reserves cannot be deployed in the time frame to assist in keeping frequency above underfrequency relay settings. Regulating Reserve usually does not respond quickly enough to be observable in the FRM. Contingency Reserves most often takes more than a minute and can take up to 15 minutes to deploy following the start of the contingency.

Regulating Reserves are 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 FRR 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 FRR and regulating reserve for the contingent responsible entity. A noncontingent responsible entity's FRR 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 FRR 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 FRR 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. FRR will always be deployed automatically and coincidentally when contingency reserve needs to be deployed for a large contingency. FRR 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 FRR 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. FRR 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 FRR would result eventually in the activation of frequency relays. As long as the amount of FRR available is greater than the energy imbalance on the Interconnection, Interconnection reliability will be supported to arrest frequency deviations.

The difficulty with operating an Interconnection with only FRR is that FRR is limited in the total amount available. FRR will arrest the frequency change but will not restore frequency to its normal range, leaving the Interconnection vulnerable to the next contingency. The FRR provided by load damping is limited and the additional FRR 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 FRR. When regulating reserve is substituted for FRR, the regulating reserve restores the FRR by returning governor response to the plants and replacing it with dispatched energy. As frequency is returned to normal range, the FRR is restored and available for reuse. The amount of regulating reserve that can be substituted for frequency response is determined by the difference between the FRR required to manage the largest imbalance that could occur on the Interconnection and the FRR that could be required in a period shorter than the response time for regulating reserve. This ensures there is sufficient FRR available to manage any imbalance occurring before there is time to replace the FRR being used with regulating reserve. Also, it extends the effective amount of FRR available, allowing the Interconnection to operate with less governor response because the amount of load damping is not easily modified.

In all cases, the maximum imbalance that is unmanageable by supplementing FRR with regulating reserve (when only FRR and regulating reserve are available) determines the minimum FRR required. In addition, the sum of the FRR and regulating reserve should exceed the largest energy imbalance occurring on the Interconnection. Thus, when substituting regulating reserve for FRR the total amount of the FRR and regulating reserve should be equal to or exceed the amount of FRR when it is used alone.

Contingency Reserves can further supplement regulating reserve and FRR and can be manually dispatched to restore any FRR currently being used to respond to declining frequency. When dispatched, it restores both FRR 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 FRR. When this substitution is implemented, the sum of the FRR, regulating reserve, and contingency reserve should exceed the sum of regulating reserve and FRR 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 FRR 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:

$$FRR + RRO \geq FRRO \qquad \textit{Inequality (1)}$$
$$FRR + RR + CR \geq FRR + RRO \qquad \textit{Inequality (2)}$$

FRRO	=	FRO, equal to MW of FRR when only FRR is used.
FRR	=	MW of FRR when another service is substituted for FRR.
RRO	=	MW of regulating reserve (RR) when nothing is substituted for RR.
RR	=	MW of RR when another service is substituted for RR.
CR	=	MW of Contingency Reserves when nothing is substituted for Contingency Reserves.

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

These inequalities are used to determine the FRO in BAL-003 as adjusted by the base frequency error profile that results 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 FRR 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 FRR is at least equal to the amount required to meet all reserve requirements concurrently.

Additionally, during the deployment of reserves in real-time, there are only limited ways to determine whether a responsible entity is holding adequate reserves. This determination can only be based on a prospective look during operations planning when there are no deviations from the expected deployment of reserves. Because this is the case, it is also 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. A reserve-monitoring tool could accomplish this.

The calculation of reserve levels (including FRR, 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 Reserves. 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.

The calculation for these three types of reserves (i.e., FRR, regulating reserve, and contingency reserve) may not be supported in some EMSs because the FRR calculation and the interaction between reserves requires additional data not currently maintained in many EMSs. Additional data required to support the FRR calculation includes, but is not limited to, unit droop, 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 that provide reserve for the responsible entity. For example, dispatch of contingency reserve from a resource could also affect the FRR 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 Reliability and Security Technical Committee Charter

NERC Operating Manual

Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation, Key Findings

Cited Documents

NERC Alert A-2015-02-05-01 Generator Governor Frequency Response

Primary Frequency Control Reliability Guideline

NERC Standard BAL-003

FERC Final Order on Third-Party Provision of Primary Frequency Response Service - FERC Docket RM15-2-000 Order No. 819

Revision History		
Date	**Version Number**	**Reason/Comments**
10/18/2013	1.0	Initial Version – "Operating Reserve Management"
12/13/2017	2.0	Revised to include more detailed description of FRSG
9/13/2020	3.0	3-year review and revisions
4/15/2021	3.0	Industry Comments addressed