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Future Ancillary Services in ERCOT

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Executive Summary

Over the years, ERCOT has been successful in complying with the National Electric Reliability Corporation (NERC) standards with the Ancillary Services (AS) that it has procured and deployed. For example, ERCOT's average monthly Control Performance Standard (NERC CPS1) scores have consistently been around 165% over the last year, which is a clear indication that ERCOT is performing extremely well in controlling frequency. Other performance measures also reflect that the ERCOT AS construct currently in place has served ERCOT well from a reliability and secure operations perspective.

In the summer of 2012, as ERCOT began discussing a pilot project to investigate a new Fast Responding Regulation Service (FRRS), several discussion items surfaced that suggested that ERCOT should "rethink" the entire existing set of AS. The following are some of the reasons that have motivated ERCOT to explore improvements and changes to the current AS approach in ERCOT:

1. The current AS construct was fork-lifted from the market design developed in the late 1990's and did not necessarily anticipate some of the changes that have taken place and the changes likely to occur in the near future.
2. Today's generation mix in ERCOT is different than the mix that existed 15 years ago.
3. Some of the new Resources expected to be added to the ERCOT system bring with them additional challenges and at the same time, some of them bring with them new capabilities in providing AS.
4. New regulatory requirements are on the horizon.
5. A new AS approach will better utilize the capabilities of the existing and new resources and will allow ERCOT to more efficiently provide the expected reliable and secure operations.
6. Improved procurement methods of AS, improved specifications of performance for Resources providing AS and the implementation of "pay for performance" settlement methods (similar to those outlined in FERC Order 755) will lead to a more efficient way to acquire and deploy AS.

This concept paper reviews the AS needs based on likely changes expected to occur in ERCOT and proposes a framework for a new Ancillary Services set to address these changes, as well as guidance for the transition from the existing AS framework.

The scope of the concept paper is limited to those physical aspects of operations related to frequency control which are currently addressed by the Regulating, Responsive Reserve and Non-Spin AS. Emergency Response Service, Voltage Support, Reliability Must-Run (RMR) units and Black Start Services are not in scope at this time.

The transition will require revisions to the Nodal Protocols and changes to the current ERCOT Operation, Market and Settlement systems. This paper is intended to provide a starting point for discussions among ERCOT Staff, the IMM, the Reliability Monitor, the PUCT and the ERCOT Market Stakeholders to achieve a consensus plan of action for addressing future AS needs, their procurement and settlement. Ultimately this consensus is expected to be reflected in the final version of this paper and provide the basis for the revisions and changes to Nodal Protocols and ERCOT Operations, Market, and Settlement and Billing Systems.

Implicit in ERCOT's analysis is the fact that ERCOT is a stand-alone interconnection and wholesale electricity market. This means that ERCOT is a single interconnection Balancing Authority (BA) – in NERC terms – and it cannot generally rely on any neighboring BA's (in the Eastern and Western Interconnections) when responding to system events and emergencies (e.g. a loss of large amounts of generation, weather initiated events etc.).

ERCOT is recommending the transition to the following five AS products:

1. Synchronous Inertia Response Service (SIR),
2. Fast Frequency Response Service (FFR),
3. Primary Frequency Response Service (PFR),
4. Up and Down Regulating Reserve Service (RR), and
5. Contingency Reserve Service (CR).

The revised AS set, as described in more detail below, adds and/or redefines specific AS products currently used by the ERCOT system; and, additionally, subsumes different elements within the current Responsive Reserve and Non-Spin Service into several of the newly defined services. During the transition from the AS set of today to the future AS set, there may be the need for a Supplemental Reserve Service that would be similar to today's 30-minute Non-Spin Service. The details of a Supplemental Reserve Service will be determined as part of the transition plan. With the exception of the SIR service, ERCOT visualizes market procurement to be similar to the existing AS procurement markets.

ERCOT suggests that its system changes and upgrades related to the new AS product set be coordinated with its system maintenance and upgrade schedules concurrently with changes that may be required in the market participant systems.

As ERCOT and the Market Stakeholders proceed, it may be determined that some of the new proposed AS may be required sooner than others (for example SIR) and that it may be best for the market if several services are grouped together and tied to the same commercial go-live date. It is expected that any major transition to a new AS set would occur after the scheduled ERCOT EMS upgrade project and therefore may not be implemented for at least 2 or 3 years.

Rethinking ERCOT's Ancillary Services

1. Introduction

The Electric Reliability Council of Texas (ERCOT) is an Independent System Operator (ISO) that serves over 23 million customers in Texas, and represents 85% of the state's electric load. The Public Utility Regulatory Act of Texas designates ERCOT as the Independent System Operator and as such ERCOT operates the ERCOT interconnect transmission system and wholesale electricity market. As defined by NERC standards, ERCOT is a single interconnection Balancing Authority (BA), which means it cannot generally rely on any neighboring BA's for sole assistance during system events and emergencies.

With approximately 11,000 MW of installed wind capacity in the ERCOT market alone, Texas has the highest levels of installed wind generation capacity of any state in the United States and expects continuing growth of renewables in the foreseeable future. ERCOT's load currently varies from a peak of slightly below 70 GW in the summer to minimum of 22 GW during off-peak seasons. The combination of huge seasonal variance in system load and high penetration of intermittent and variable renewable generation resources, such as wind generation, increases ERCOT's operational challenges significantly. Nevertheless, ERCOT has been successfully operating the system with high wind penetration over the past years. ERCOT has developed unique expertise on wind generation capabilities, deliverability and impact of wind generation on power system, which, along with constantly improving wind power forecasting tools, allows ERCOT to better predict AS needs. ERCOT expects to utilize a similar approach as other intermittent and variable generation resources become an increasing share of the ERCOT resource set in the future.

In December 2010 ERCOT implemented the current ERCOT Nodal Market. In this market resource scheduling and dispatch became resource-specific as opposed to the portfolio-based approach in the previous Zonal Market. This change has led to improved efficiencies in unit commitment and dispatch across the ERCOT system. The introduction of the Nodal Market was one of the key factors contributing to the successful integration of intermittent resources into the ERCOT system. Resource-specific dispatch with 5-minute resolution allows ERCOT to closely follow net load variations and is one of the main reasons why ERCOT has been successful in integrating renewables with minimal increase in AS capacity.

The current AS framework for the ERCOT Region was designed when large steam generators were the predominant generation type in ERCOT. These units have certain inherent characteristics and the Ancillary Services framework was designed around those characteristics. This framework has gradually, but significantly, evolved as gas-fired combined cycle plants and wind generators have become larger portions of the generation mix. However, it has become more difficult and less efficient to continue with the current AS set while accommodating emerging technologies and the evolving capabilities of existing resources. The current effort to review ERCOT's AS set is intended to ensure the continued reliability and security of the ERCOT system, taking into consideration existing and emerging technologies.

In the last decade new generation technologies have begun to appear, e.g. non-synchronous generation (wind and solar), as well as battery storage, connected to the ERCOT grid via power electronic inverters. These technologies have very different characteristics and performance compared to the conventional synchronous generation fleet. For example:

- Inverter based generation technologies and battery storage do not contribute to system inertia; and
- Solar and wind generation are intermittent in nature and power output cannot be accurately predicted.

On the other hand, the frequency response provided by a battery or wind generator is controlled by the inverter electronics and has the potential to respond faster than that of conventional generators. ERCOT has strived to propose a revised AS framework that is based on the fundamental needs of the power system to maintain frequency control, is as neutral as possible to the technology types that are able to provide the services, and avoids unnecessary restrictions that limit the provision of the fundamental AS requirements by as broad a set of resources as possible.

2. New Resource Characteristics

The increasing penetration of non-synchronous resources leads to economic displacement of some synchronous generators that would otherwise be committed to serve a given load. Because these non-synchronous resources are electrically connected to the system through an electronic inverter, these resources typically do not contribute inertia to the system, resulting in an overall reduction in the system inertia within the ERCOT Interconnection. Figure 1 shows the effect of declining grid inertia within ERCOT interconnection from 2006 to 2010. The Data Set I includes 43 historical events with an average wind generation of 1157 MW and an average 557 MW unit trip. The events in Data Set I include frequency disturbance events during the periods of January to May and October to December in years 2006 & 2007 and January to May of 2008. Data Set II consists of 44 historical events with an average wind generation of 2490 MW and an average 595 MW unit trip. Data Set II includes frequency disturbance events during the periods of October to December of 2008, January to May and October to December of 2009 as well as January to April of 2010 [1].

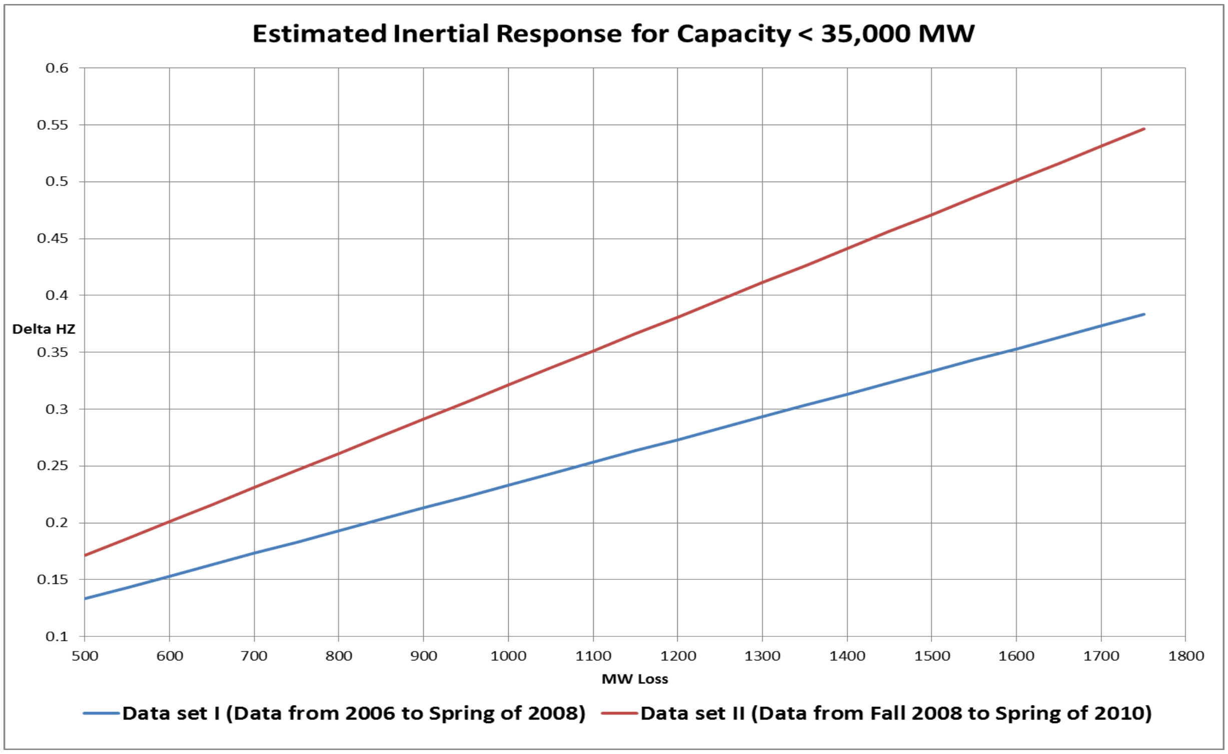


Figure 1: Interpolated Inertial Frequency Response

This analysis shows a decline of system inertial response for the Data Set II (Red) compared to Data Set I (Blue) for the same type of events during similar system conditions with total on-line conventional generation capacity less than 35,000 MW, which results in larger frequency delta (Y-axis) for the same MW loss (X-axis). The decline in Inertial Response leads to faster frequency decay and lower frequency nadir during a generation resource forced outage (refer to Figure 2 below) as well as more severe changes in frequency due to normal load and generation variations. Additionally, the decline in Inertial Response will also result in larger frequency deviation for smaller unit trips and potentially trigger Under-Frequency Load Shed ("UFLS") more often.

ERCOT currently estimates that the penetration of renewable resources has the potential to increase to as much as 16 GW within the next few years and may further increase in the longer horizon [2]. The displacement of synchronous generators as the result of the increased wind production has the potential to further reduce the system inertial response capability. The current AS set is not specifically designed to address this challenge.

3. New Regulatory Requirements

The recently FERC approved NERC BAL-003 standard [4] requires each Balancing Authority to meet a minimum Frequency Response Obligation (additional detail on this standard is discussed below). NERC also recently circulated a Reserve Policy guideline which reaffirms its support for maintaining Frequency Responsive, Regulating and Contingency Reserves. The Reserve Policy applies to ERCOT and the objective of this reliability guideline is to identify key practices and information on specific issues critical to maintaining the highest levels of Bulk Electric System reliability [3].

4. Need to Maintain System Frequency and Capacity Reserves

This section describes the concerns and challenges for today's AS products in the foreseeable future and identifies the need, from a system perspective, for AS related to system frequency and capacity reserves to maintain adequate system security and reliability.

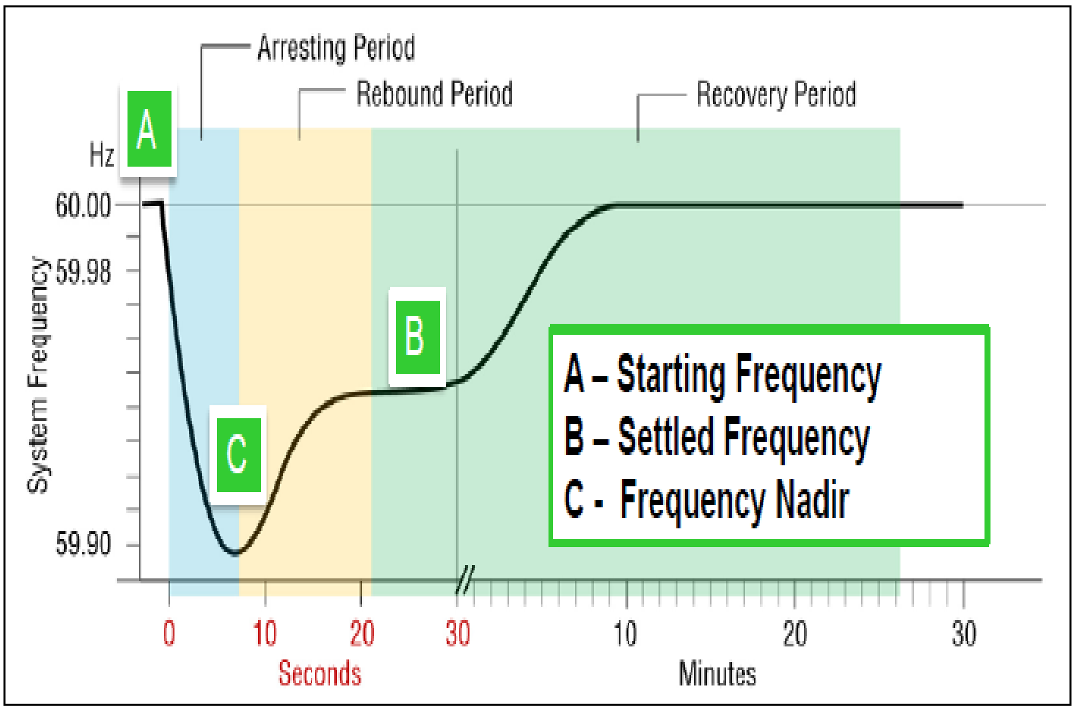


Figure 2: Typical frequency response following a generator trip.

Following disturbances in a power system all online synchronous machines provide Synchronous Inertial Response (SIR). This response has significant implications on the rate of change of frequency (RoCoF) during sudden power imbalances. With an increasing amount of non-synchronous generation (e.g. wind generators) this response is reduced and RoCoF becomes higher, leaving insufficient time for other reserves to deploy and arrest the decline in system frequency before it drops to an unacceptable level [5].

As described in the following, the situation is complex and there are a number of factors that must be considered in the analysis of the system response and potential mitigating services. For example, with less synchronous generation online, there is a need for fast-acting response to changing frequency in the immediate post event time period. Fast Frequency Response (FFR) defined as active power response faster than the Primary Frequency Response (PFR) may, in the event of a sudden power imbalance, increase the time to reach the frequency nadir and mitigate the RoCoF, thus allowing sufficient time for PFR to respond [5]. Since ERCOT is a single Balancing Authority Interconnection and is not synchronously connected with any other interconnections, ERCOT needs a PFR service to maintain stable frequency and meet NERC standard requirements. Additionally, recently approved NERC BAL-003 standard also requires ERCOT to meet minimum Frequency Response Obligation which is based on instantaneous loss of two largest units (2750 MW).

Normal system operations require Regulating Reserves (RR) services to provide secondary frequency response and are used by the BA's Load Frequency Controller to match demand with supply every four seconds. RR are primarily needed to maintain good frequency control around the nominal frequency control point of 60 Hz and meet the NERC Control Performance Standard (CPS1). Each BA is required to maintain its rolling 12-month CPS1 Score higher than 100%. ERCOT's current CPS1 score is above 165%. Generally, during contingency events, it is expected that both PFR and Regulation-Up will be deployed to recover from the event.

Additionally, NERC Standard BAL-002-1 Disturbance Control Standard (DCS) requires ERCOT to carry enough reserve to recover its Area Control Error ("ACE")[1] to pre-disturbance level, post DCS event, within 15 minutes. In the NERC parlance, capacity reserves that are utilized for this purpose are referred to as Contingency Reserves. The purpose of the Contingency Reserve is to ensure that the Balancing Authority (ERCOT) is able to restore Interconnection frequency within defined limits following a DCS event and restore its Primary Frequency and Regulating Reserve capacity to pre-disturbance level. In order for ERCOT to meet the requirements of the NERC Reliability Standard (BAL-002), ERCOT needs to identify its "Most Severe Single Contingency" to determine its minimum Contingency Reserve requirement.

5. Proposed Type of Services

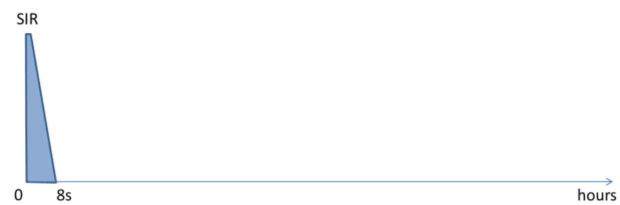
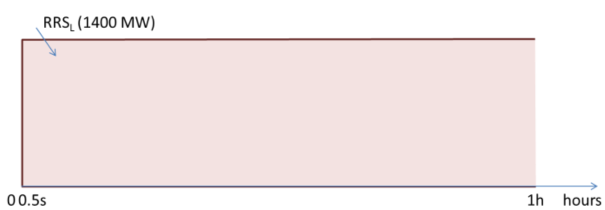
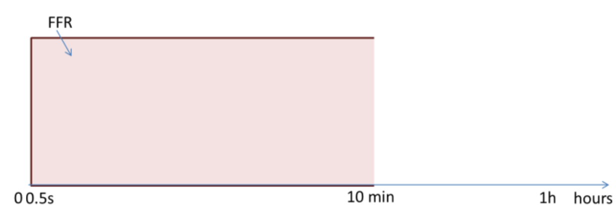
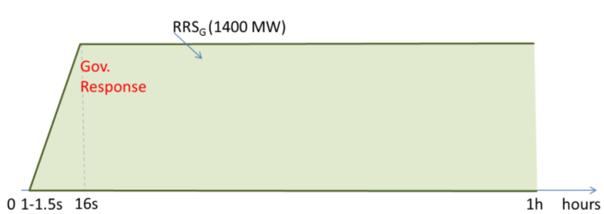
To continue to operate reliably and meet regulatory standards, ERCOT is proposing that its AS product set be revised to provide the following five types of AS:

1. Synchronous Inertia Response Service (SIR),
2. Fast Frequency Response Service (FFR),
3. Primary Frequency Response Service (PFR),
4. Up and Down Regulating Reserve Service (RR), and
5. Contingency Reserve Service (CR).

[1] The ACE is an error signal generated in the ERCOT Load Frequency Control system that determines the direction and magnitude of the regulation control signals provided to those resources providing Regulation Up or Down AS.

The deployment of the reserve categories represented by these five AS are governed primarily by NERC Reliability Standards including Regulating Reserve to meet the CPS1 Standard (BAL-001), Contingency Reserve to meet the DCS Standard (BAL-002) and Primary Frequency Response to meet the Frequency Response Obligation Standard (the newly FERC approved BAL-003 standard). How well ERCOT meets these reliability metrics also depends on the interaction of the proposed Synchronous Inertial Response Service and FFR.

The table below summarizes existing AS framework (left column) and proposed future AS framework (right column). For each service the expected time to respond to a deployment signal and the time to deliver full deployed capacity is shown. The last row of the table illustrates total make-up of current and proposed AS.

Current Ancillary Services Framework	**FutureProposed Ancillary Services Framework**
	Synchronous Inertial Response 
Responsive Reserve Service from Load 	Fast Frequency Response (need to hold for 10 min) 
Responsive Reserve Service from Generation and other Governor Reponse. 	Primary Frequency Response 

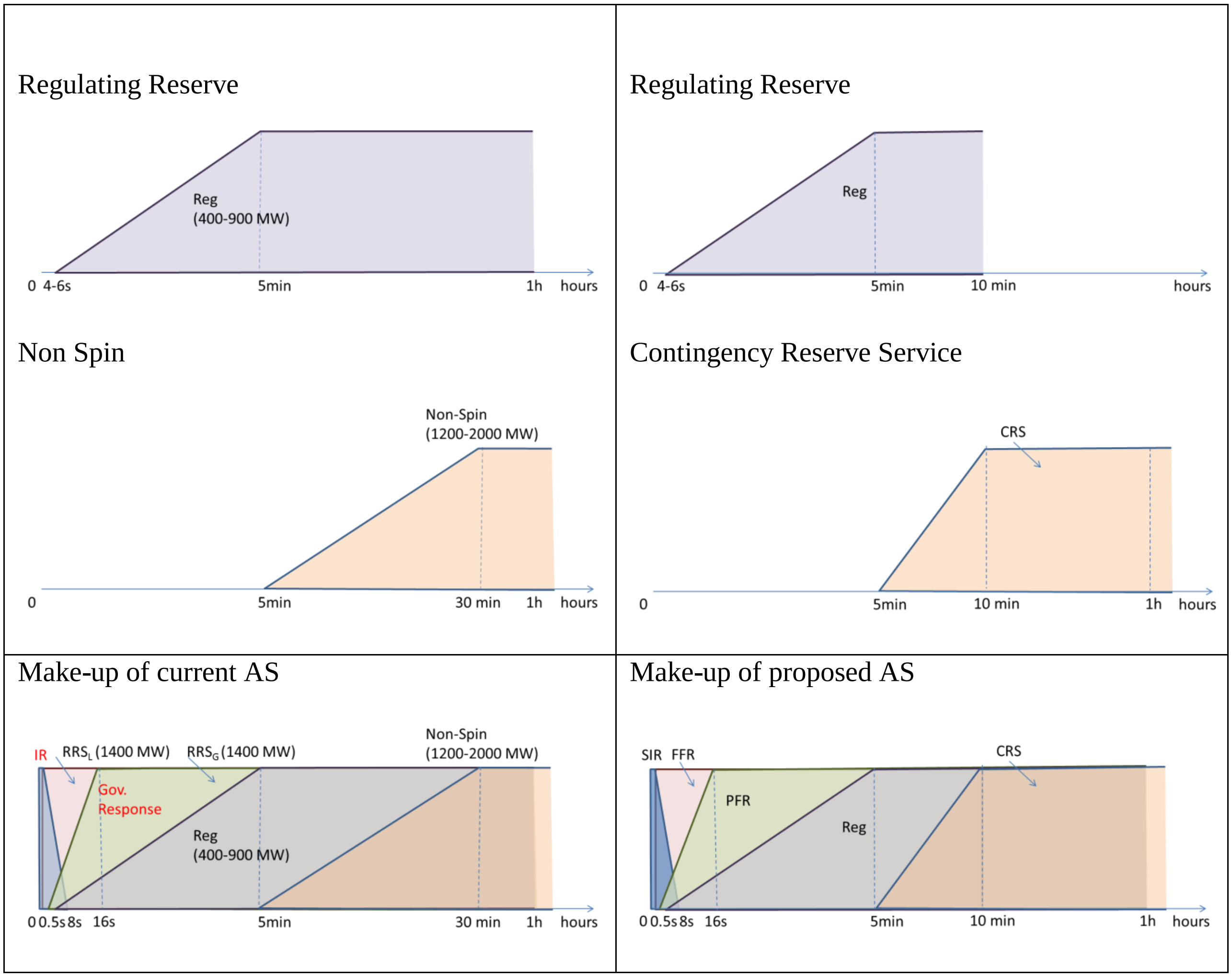


Table 1: Existing and Proposed AS Frameworks

6. Synchronous Inertial Response (SIR) Service

Need for SIR Service

Synchronous Inertial Response has significant implications on the rate of change of frequency (RoCoF) during power imbalances. With increasing non-synchronous generation SIR is reduced and RoCoF increases, leaving insufficient time for PFR to deploy and arrest system frequency decline[5], i.e. time between point A and C, Figure 2. High RoCoF may also trigger generator's RoCoF protection tripping additional synchronous generation as a result. There is therefore a need to assure the provision of a sufficient amount of inertial response on the ERCOT system. SIR service is intended to meet this need.

Purpose of SIR Service

Synchronous Inertial Response (SIR) is an instantaneous response that is continuously self-deployed from synchronous machines following disturbances and is a key determinant of the strength and stability of the power system. Synchronous Inertial Response is defined as stored kinetic energy (at nominal frequency) that is extracted from the rotating mass of a synchronous machine following an imbalance in a power system. Stored kinetic energy is based on the commissioned design capability of the plant. It can be determined through appropriate validation procedures based on the following relationship:

Stored kinetic energy = $J\omega_0^2/2 = H \cdot MVA$,

- Where; the stored kinetic energy is in Mega Watt – Seconds;
- J is the combined moment of inertia of a synchronous machine and turbine prime mover in $kg \cdot m^2$, based on their size and weight;
- ω_0 is the nominal rotor speed in rad/s, and
- MVA is the machines rated capacity in Mega Volt – Amperes.
- H is the figure of merit used to analyze the synchronous machine's inertial response and is referred to as the machine's inertial constant in seconds.

Solving for H the above equation results in $H = J\omega_0^2/(2 \cdot MVA)$ seconds.

The inertia response that a synchronous machine can provide is independent of the machine's power output and the total system response to an initiating event is determined by the summation of the contributions from each of the online synchronous machines. ERCOT will determine by analysis the desired response of the system under the largest generator trip event. How much SIR ERCOT requires, will be based on $f_{nadir}>59.3$, that is more than prevailing initial threshold of UFLS and RoCoF limitations implied by RoCoF protection settings of synchronous generators in ERCOT system. The proposed constraint imposed on the unit commitment is that the summation of inertia contributions from each of the synchronous machines, committed for energy and AS, must achieve the required system inertial response.

Resource performance will be evaluated based on machine parameters (H and rated MVA) and machine status (online/offline) and every individual synchronous resource capable of providing this service will be required to provide ERCOT with machine specific data (via the RARF) and telemetry of its status.

As of July, 2013 ERCOT's record for wind penetration as a percent of total instantaneous load is 35% at 3:16 on March 3, 2013. The RoCoF during high wind low load condition was less than 0.2 Hz/second and the average time to reach frequency nadir during frequency events is within 4 to 6 seconds. Therefore, the system inertia available in the real time operations under current conditions is still sufficient. However studies based on 2012 system conditions indicated RoCoF as high as 0.4 Hz/s for two largest unit trip (2750 MW as per recently approved NERC BAL-003 standard). Since there is a declining trend of ERCOT's inertial response, ERCOT will continue monitoring real time instantaneous penetration of non-synchronous generation and RoCoF during frequency events, and determine when system inertia becomes a reliability concern.

Synthetic SIR Service

Inverter based wind turbine generators (WTG) and other inverter based resources can have the capability to inject active power into the system initiated through control system action following a disturbance, e.g. generator trip. This capability, so called synthetic inertia, is already available from several WTG manufacturers. Figure 3 below illustrates synthetic inertia response from a wind power plant with synthetic inertia capability in Hydro Quebec [6]. This capability can be achieved without pre-fault wind energy curtailment. However, when a wind turbine is operating just below rated wind speed there will also be a recovery period shown in Figure 3 below.

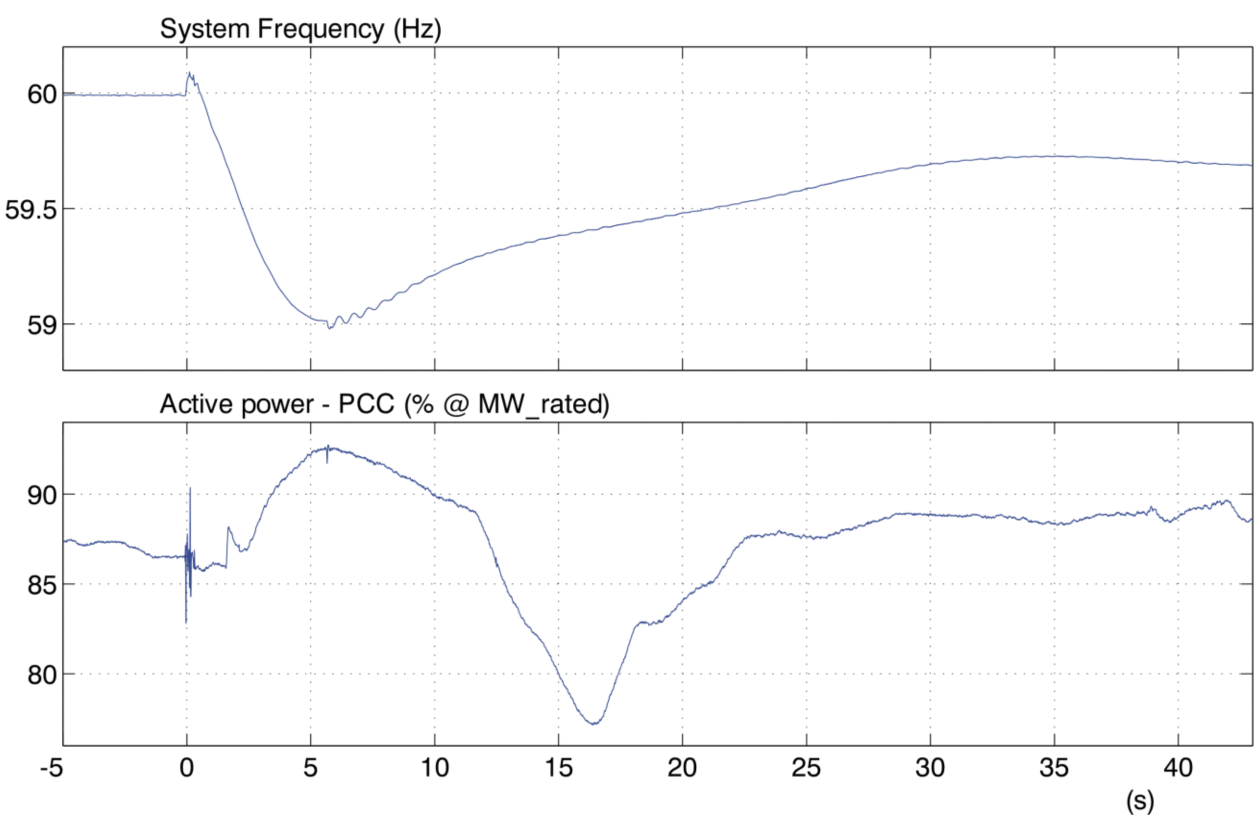


Figure 3: Synthetic inertia response from a wind power plant, example of a recorded event in Hydro-Quebec[6] (PCC – Point of Common Coupling, connection point to the grid)

Synthetic inertia capability requires control action in response to falling system frequency and therefore is not equivalent to synchronous machine inertia, which is a natural response of synchronous machines to a generator trip. However synthetic inertia will improve RoCoF and help to arrest system frequency decay. More discussion and evaluation of synthetic inertia performance is required.

Market Construct for SIR

In the near-term, there may be sufficient SIR available naturally to preclude the need for an explicit procurement of this service. Consequently, ERCOT suggests that this service be considered on a different time track and implementation sequence. For this service, a manual implementation as part of the RUC process could be developed first with the market system changes following as soon as practical.

For the initial rollout of procuring the SIR service, ERCOT shall determine the amount of SIR that is required for each hour, however there will not be a market for this service and no clearing prices for SIR. The required amounts will be acquired through a RUC process if necessary. The RUC optimization engine will seek a resource commitment solution that minimizes resource costs for the Operating Day while simultaneously satisfying the requirements for an amount of SIR service in each Operating Hour based on the physical attributes of the RUC committed resources capable of providing an SIR response. The resulting RUC unit commitment will represent the least cost commitment and energy dispatch that simultaneously satisfies the SIR constraint. In the event that the RUC SIR constraint is not satisfied by the final RUC commitment, ERCOT Operations will use a manual processes to satisfy the required system SIR response.

Note that DAM is not considered as the method to procure this service as resource participation in DAM is voluntary and the DAM results are financially binding, not physically binding. Also from a market pricing process, an inertia response is not provided instead of anything else; therefore, there is no opportunity costs due to this service, no explicit offer into the DAM and the DAM shadow price associated with this service cannot be interpreted as representing an opportunity cost.

More discussion will be required to explore the possibility of creating a market for SIR service. One of the options that can be considered is the use of an administrative sloped SIR demand curve coupled with SIR offers at a price of zero. In the RUC process, the resulting intersection of the SIR supply and demand curve will determine the clearing price of this service. This clearing price will be paid to all Resources providing this service. Discussion needs to include topics such as mitigation of market power, ability to incorporate non-zero SIR Offer prices, etc.

Transition and Implementation Considerations for SIR

Implementation details that require further study include, but are not limited to, the identification of:

- RUC inputs for units capable of providing a SIR response,
- Requirements that may be specific to units capable of providing SIR response,
- RARF data requirements, and
- The need for generic defaults to satisfy the required RUC inputs, and
- ERCOT qualification and performance monitoring systems.

As noted earlier, in the event that the RUC SIR constraint is not satisfied by the final RUC commitment, ERCOT Operations will use a manual process to satisfy the minimum required SIR. Incorporating minimum SIR requirements in RUC as well as associated manual process will require extensive modifications. RUC logic for SIR and unit commitment and de-commitment rules will need to be developed to guide ERCOT Operators in the execution of the RUC processes. The RUC make whole logic will also require revision to address cost recovery issues that are created by unit commitment instructions. These updates to the RUC process are a critical milestone in the implementation timeline for this service.

7. Fast Frequency Response (FFR) Service

Need for FFR Service

With less synchronous generation online, there is a need for fast-acting response (full response delivered within 0.5 seconds) to changing frequency. This fast response can supplement the inherent inertial response from synchronous machines, thus helping with the symptoms of low system inertia. It should be pointed out that FFR cannot completely replace system inertia and will only increase time to frequency nadir allowing sufficient time for PFR to deploy. Presently there is no Fast Frequency Response Service in ERCOT, however up to 1400 MW of Responsive Reserve Service (RRS) procured from Load Resources (LR) satisfy FFR characteristics as defined below. Furthermore, multi-stage deployment at different frequency thresholds are proposed to provide adequate support while minimizing the amount of FFR deployment during frequency events.

Purpose of FFR Service

Fast Frequency Response (FFR) is MW response faster than the existing PFR. It will, in the event of a sudden power imbalance, increase the time to reach the frequency nadir and mitigate the RoCoF in the same period.

During periods with low inertia, i.e. periods with low load/high non-synchronous generation, in the absence of this service much higher capacity of PFR will be needed to ensure that sufficient capability is available to arrest fast frequency decay in the event of sudden power imbalance.

Fast Frequency Response service is expected to provide instantaneous increase in active power output from a Resources or instantaneous reduction in demand, following a frequency event that is fully deployed within 30 cycles (0.5 seconds) at a specified frequency threshold and sustained for at least 10 minutes.

Measurement of FFR will require a high resolution recording device, for example a Phasor Measurement Unit (PMU), to be installed at the provider's site with appropriate communication for ERCOT.

In the current AS framework, Load Resources can provide up to 50% of RRS. In this proposed AS framework, FFR and PFR are highly interdependent and the needs can vary based on the system condition. The amount needed for FFR and PFR are described in the section of Primary Frequency Response (PFR) Service.

Market, Transition and Implementation Considerations Associated with FFR

Market, transition and implementation considerations associated with FFR are discussed below in the PFR section since FFR and PFR have an interdependency.

8. Primary Frequency Response (PFR) Service

Need for PFR Service

ERCOT is a single Balancing Authority Interconnection and is not synchronously connected with any other interconnections, therefore, ERCOT is solely responsible for maintaining frequency to maintain reliability and meet NERC standard requirements. Within ERCOT all of the frequency response can only come from Resources within the ERCOT Interconnection. On July 18th, 2013 FERC issued a Notice of Proposed Rule Making (NOPR) approving the BAL-003 NERC Frequency Response Standard which sets Frequency Response Obligation (FRO) for each BA. This requirement sets minimum FRO for ERCOT at 286 MW/0.1 Hz [4].

At a minimum, PFR ancillary service should encompass response characteristic designed to meet the following two types of response:

1. Arrest the Frequency Decay and re-set frequency closer to 60 Hz (settling Frequency), shown as rebound period in the Figure 2.
2. Resources providing PFR must be able to respond proportionally to frequency deviation.

Definition of PFR

Primary Frequency Response (PFR) can be defined as the instantaneous proportional increase or decrease in real power output provided by a Resource in response to system frequency deviations. This response is in the direction that stabilizes frequency. Primary Frequency Response is attained due to Governor or Governor like action to instantly act relative to the frequency deviation, this response is generally delivered completely within 12 seconds to 14 seconds. The ability of ERCOT Grid to stabilize after a sudden loss of generation is dependent on sufficiency of primary frequency response. Resources providing primary frequency response must be able to provide continuous full proportional response against the frequency deviation. The performance of these Resources will be measured as defined below;

1. Full proportional response must be delivered by 16 seconds (B point) from A point (see Figure 2), droop response will be calculated at 16 seconds; and
2. Full proportional response must be sustained for an additional 30 seconds after B point, and droop response will be calculated at 46 seconds.

Governor Setting Requirement for Generation Resources

A Governor with droop setting not to exceed 5% shall be in-service whenever the Generation Resource is providing energy to the ERCOT Transmission Grid. All the resources with PFR responsibility shall have the Governor Dead-Band no greater than +/- 0.036 Hz. As a concept, Resources without a PFR responsibility may have the Governor Dead-Band bigger than what is required for Generators that are providing PFR so that these Generators are not required to provide PFR during normal frequency excursions.

Resource Limit On Carrying PFR

Resources will be allowed to carry PFR reserve up to the capacity that can be deployed by Governor Action for a 1% change in Frequency outside Governor Dead-band (See Figure 4). The amount of PFR that can be deployed by Governors for a 1% change in frequency outside the Governor Dead-band, will be based on the median of actual performance of each Generation Resource and Controllable Load Resource in the last three measurable events measured at B point and B+30 seconds point.

This methodology would provide incentives for resources to improve their droop performance to carry more PFR capacity. Another advantage with a performance based approach is, as Resources start performing poorly, they will be limited on how much PFR they can carry hence more resources will be carrying PFR reserves which would further improve Grid Reliability. The performance based PFR capacity limit will work as closed loop feedback to improve PFR performance.

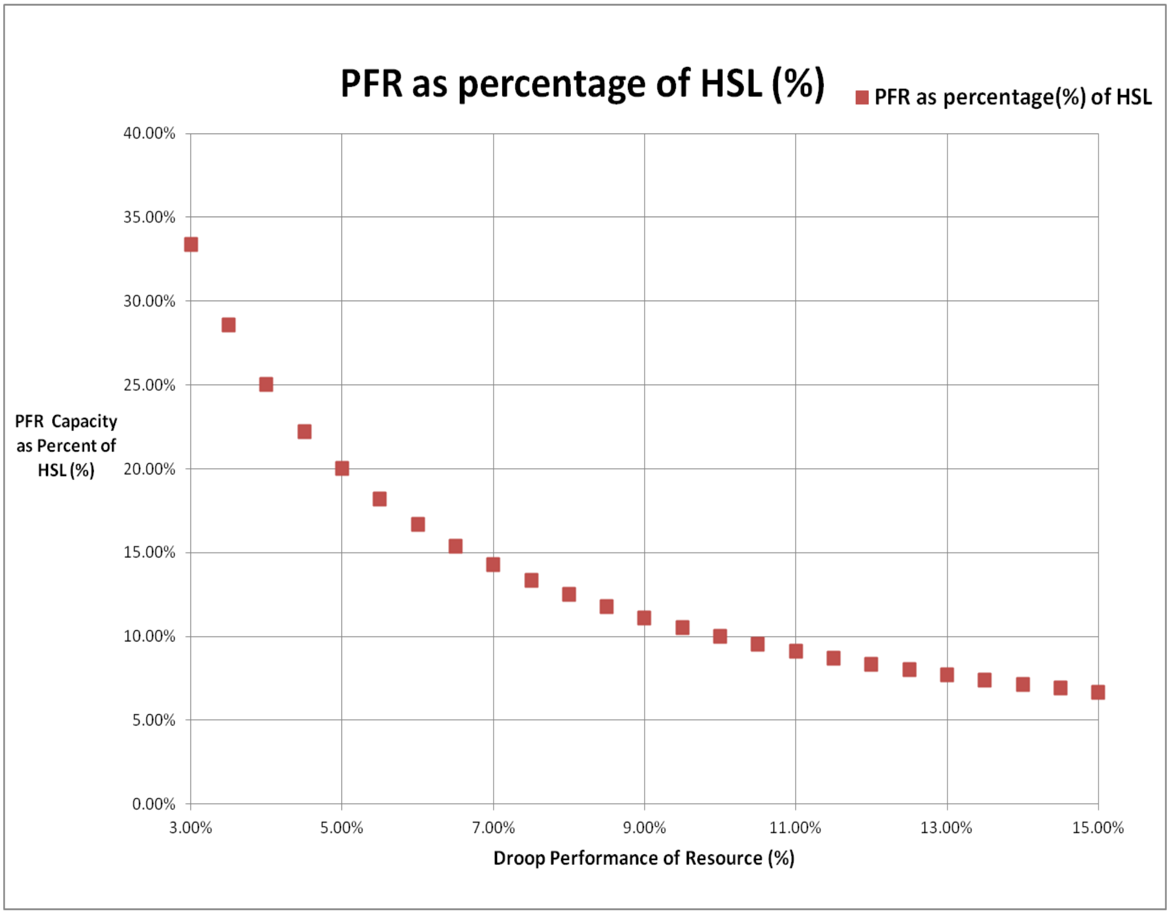


Figure 4: Resources Ability to Carry PFR Capacity as Percent of HSL Based on Droop Performance

Determination of Amount of FFR and PFR Reserve Needed

The objective of Fast Frequency Response (FFR) and Primary Frequency Response (PFR) Reserves should be to ensure Frequency is arrested above the Under-frequency Load Shedding (UFLS) threshold of 59.30 Hz and to meet NERC FRO Standard (BAL-003). Frequency Response Obligation (FRO) for ERCOT is determined based on instantaneous loss of two largest nuclear units (2750 MW). In the current AS framework, Load Resources can provide up to 50% of 2800 MW RRS. The results in the ERCOT 2012 Load Resources assessment[2] further indicated a need of a minimum of 2800 MW total RRS under certain worst case conditions, if that total meets certain minimum Load Resources participation criteria, otherwise additional RRS provided by Generation Resources needs to be procured to provide acceptable response for

[2] Available at http://www.ercot.com/calendar/2012/06/20120614-ROS

the outage of two largest units. In this proposed AS framework, therefore, FFR and PFR are highly interdependent and the needs can vary based on the system condition. ERCOT should regularly perform the assessment to determine and revise the amount needs for both FFR and PFR.

The previous study by System Planning, described above, indicates that a minimum of 2800 MW total PFR and FFR Reserve would be required to meet the FRO requirement, if that total meets certain minimum FFR participation criteria, otherwise additional PFR would be required. Table 2 below illustrates the concept of interdependency between FFR and PFR.

System Load	FFR	PFR(5% Droop)
<=35000 MW	840 MW(30% 0f 2800)	1960
<=35000 MW	0 MW	4480 MW

Table 2: Requirements for Combined FFR and PFR

Market Construct for FFR and PFR

The desired system response characteristics to an under-frequency contingency event can be achieved with different amounts of FFR and PFR but the amounts required are interdependent. Because of this interdependent relationship and substitution capability, ERCOT proposes to treat the FFR and PFR services as a single market. ERCOT also proposes that further discussions, as described below, are needed with regard to substitution rules or the separation of the PFR and FFR markets before adopting further changes to the existing market structures for these two services.

ERCOT will determine the total requirement for the sum of FFR and PFR services for each Operating Hour and procure in the DAM an amount of FFR and PFR capacity that satisfies the total requirement. The total obligation for these services will be allocated on Load Ratio Share (LRS) basis and self-arrangement is allowed. QSEs representing Resources that are qualified to provide PFR service may submit offers in the DAM to provide either PFR Service or energy and the DAM optimization engine will award the service based on the co-optimization of the cost of the PFR capacity reservation or energy production, subject to the constraint on the total FFR plus PFR awards. If the DAM is unable to satisfy the total FFR plus PFR constraint, ERCOT will use the RUC process to assure that the FFR plus PFR service requirement is met. The SASM process will be utilized to address shortage issues that arise because of AS infeasibility, failures to provide the service, or the need to procure additional PFR and FFR service during the Operating Day. Resources awarded PFR service will require a HASL set point that includes the PFR capacity procured by ERCOT.

In addition to the substitution issues discussed above, ERCOT also wants to designate a minimum amount of FFR service when appropriate. Because of the very short response time upon activation of the FFR service, ERCOT wants to be able to require that a minimum amount of FFR service be online in each operating hour when it is necessary to assure an acceptable system response to the most limiting event applicable for that operating hour. Similarly, there may be conditions under which a minimum amount of PFR service is required. Consequently, ERCOT proposes consideration be given to procuring a minimum amount of each service (FFR and PFR) when needed with the balance of the system needs satisfied solely by the economic optimization between FFR and PFR services, subject to substitution rules.

ERCOT is concerned with several market issues that could potentially arise with the introduction of PFR and FFR services as stand-alone services. The opportunity cost associated with this service differ depending on the division of the service into a required minimum amount and the balance of the system requirements for FFR and PFR services. In the case of the minimum procurement amount, the opportunity cost associated with FFR provided by Load Resources is a forward cost incurred by the loss of productivity represented by the disconnected load offset by savings attributed to reduced energy billings. Other than the submitted offers, ERCOT systems have no way to value these components for inclusion in the DAM constraint model; the constraint model will simply require a minimum procurement amount. On the other hand, FFR providers will directly compete with PFR provides for the remaining FFR required capacity required to fill out the AS Plan requirements. FFR offers will be valued according to the DAM co-optimization of PFR reservation capacity and energy. The difference in pricing between these two capacity regimes will affect the clearing price for the FFR service. If the clearing price for FFR service is determined by the highest offer struck to achieve the minimum FFR procurement amount, there may be no price incentive for offers beyond this amount.

Transition and Implementation Considerations Associated With FFR and PFR

The implementation of this service in the ERCOT Operations and Market Operations Systems will require Nodal Protocol changes and extensive process and system upgrades. These changes will address the following:

- ERCOT Operations AS Plan, AS Qualification and Monitoring processes,
- ERCOT Market Operations DAM and SASM procurement processes (including substitution rules),
- The ERCOT RUC process, and
- ERCOT Settlements and Billing processes. and
- ERCOT qualification and performance monitoring systems.

It is noteworthy, that the efficient use of generation resources and the consequent minimization of energy cost would be significantly enhanced by the implementation of a near real time procurement process based on a multi-interval commitment process. Such a process would provide superior results in the energy, FFR and PFR co-optimization during real and near real time intervals.

For a variety of reasons, including system reliability and security, operation within the NERC standards, and good utility practice, ERCOT also proposes to continue the requirement that all units capable of governor response have their governors in service; however, units that do not have a PFR service responsibility are not required to reserve capacity for governor action and may be allowed to have a larger frequency dead-band.

9. Regulating Reserve (RR) Service (Up & Down)

Need for Regulating Reserve Service (Up & Down)

ERCOT generation is dispatched through Security Constrained Economic Dispatch (SCED) to balance the generation and demand. The power imbalance between each SCED interval will cause frequency deviation that requires regulating reserve to compensate. RR service will not substantially change from where it is today. The proposed changes are discussed in next section.

Purposed changes for RR Service (Up & Down)

When calculating the amount of RR needed, ERCOT should take into account the net load variability, short-term load forecast and the probability of extreme changes such as weather.

Since RR is intended to balance the system between five-minute SCED intervals, their deployment and recall capability needs to be consistent. Resources providing RR should be limited to min(NURR,NDRR)*5*0.70, where NURR and NDRR are Normal-Up Ramp Rate and Normal-Down Ramp Rate The factor of 0.7 is included to prevent SCED from using up the entire ramping capability on units carrying RR, thus leaving 70% ramping capability to respond if Regulating Reserve deployment is needed. .

Resources providing regulating reserve should be able to closely follow ERCOT Load Frequency Control (LFC) signal for RR to be effective. LFC signals will be delivered by ERCOT to the Resource providing this service (i.e. the QSE fleet deployment of Regulation services will be discontinued). The deployment instructions will be determined by taking into consideration parameters of each individual Resource. The performance measurement should include a metric that correctly measure a Resource’s ability to follow the ERCOT LFC signal and the pay for performance metric should be considered to encourage each Resource to enhance their performance.

Resources providing RR service must be able to deliver and sustain the reserve deployments for up to 10 minutes. ERCOT will have to re-visit its LFC and Resource Limit Calculator (RLC) in order to minimize deployments of RR for more than 10 continuous minutes in one direction during normal operation.

Market Construct for RR (Up & Down)

ERCOT will determine the required amount of RR-Up and RR-Down capacity for the system for each Operating Hour and procure the needed amount of RR capacity in the DAM. QSEs representing Resources qualified to provide this service may submit offers in the DAM to provide either RR Service or energy and the DAM optimization engine will award the service based on the co-optimization of the cost of the RR capacity reservation or energy production. RR Obligations will be allocated on LRS and self-arrangement is allowed. If the DAM is unable to award sufficient RR service, ERCOT will use the RUC process to assure that the RR service requirements are met. The SASM process will be utilized to address RR shortage issues that arise because of AS infeasibility, failures to provide the service, or the need to procure additional RR service during the Operating Day. Resources awarded RR will require a LASL/HASL set point that includes the RR capacity procured by ERCOT.

Transition and Implementation Considerations Associated with RR (Up & Down)

The implementation of RR in the ERCOT Operations and Market Operations Systems will require Nodal Protocol changes and extensive process and system upgrades. These changes will address the following:

- The ERCOT and QSE SCADA systems,
- ERCOT Operations AS Plan, AS Qualification and Monitoring processes,
- ERCOT Market Operations DAM and SASM procurement processes (including substitution rules),
- The ERCOT RUC process,
- ERCOT Settlements and Billing processes, and
- ERCOT qualification and performance monitoring systems.

10. Contingency Reserve (CR) Service

Need for CR Service

NERC Standard BAL-002-1 Disturbance Control Standard (DCS) requires ERCOT to carry enough reserve to recover its Area Control Error (ACE) to pre-disturbance level, post DCS event, within 15 minutes. In order for ERCOT to meet the requirements of the NERC Reliability Standard (BAL-002), ERCOT needs to identify its "Most Severe Single Contingency" to determine their minimum Contingency Reserve requirement.

Purpose of CR Service

Contingency Reserve is to ensure that Balancing Authority is able to restore Interconnection frequency within defined limits following a DCS event within 15 minutes and restore its Primary Frequency and Regulating Reserve.

The minimum amount of Contingency Reserve required is equivalent to BA’s Most Severe Single Largest Contingency, in ERCOT’s case this would be 1375 MW. To ensure ERCOT can meet the DCS standard, the CR must be fully deliverable within 10 minutes so that Frequency can be restored to the pre-disturbance level within 15 minutes.

ERCOT Operations will establish a process to identify and flag any need for additional capacity through RUC process (same concept as ERCOT Reliability Assessment Tool (ERAT)[3]).

Qualification of Resources for CR Service

Generating Resources providing CR should be qualified up to the MW value they are able to ramp-up within 10 minutes from the time of deployment. Similarly Load Resources should be qualified for CR based on their ability to decrease its energy consumption within 10-minutes from the time of deployment. ERCOT will deploy CR for a sizable generation or load tripping. Resources providing CR must telemeter their ramp-rates such that SCED can dispatch the full Resource CR responsibility within 10 minutes.

Performance Measurement of Resources Providing CR

Resources providing CR should deploy at least 95% of the responsibility within 10 minutes after receiving ERCOT deployment signal. A resource will be disqualified if it fail two consecutive deployments.

Market Construct for CR

ERCOT will determine the minimum required CR for the system for each Operating Hour and procure the needed amount of CR capacity in the DAM. QSEs representing Resources that are qualified to provide this service may submit offers in the DAM to provide either CR or energy and the DAM optimization engine will award the service based on the co-optimization of the cost of the CR capacity reservation or energy production. CR obligations will be allocated on LRS and self-arrangement is allowed. If the DAM is unable to award sufficient CR, ERCOT will use the RUC process to assure that the CR requirement is met. The SASM process will be utilized to address CR shortage issues that arise because of AS infeasibility, failures to provide the service, or the need to procure additional CR during the Operating Day. Resources awarded CR will require a HASL set point that includes the CR capacity procured by ERCOT.

[3] ERAT is a tool developed at ERCOT to assess operational, e.g. day ahead or hour ahead, loss of load probability LOLP.

11. Global Market, Transition and Implementation Considerations of New AS

With certain exceptions described below, ERCOT visualizes an AS market procurement process similar to the existing process and continued use of the current market systems. The new AS products will be incorporated in ERCOT's daily AS Plan and the required AS services will be procured in the Day Ahead Market just as they are in today's market. The RUC process will continue to be the backup process for assuring that the requirements of the AS Plan are met and the SASM process will continue to be used to address changes in AS responsibility due to AS infeasibility, failures to provide the service, or to satisfy the need for additional AS during the Operating Day. ERCOT also suggests that consideration be given to implementing FFR, PFR, and CR concurrently with the same commercial operation date. Depending on future resource additions in ERCOT, the Synchronous Inertial Response service may be required to meet system stability requirements before it is possible to complete the system changes required for these three services.

The RR services provide the most flexibility with regard to an implementation schedule. Since this service's functionality is maintained between the current and proposed AS product sets, its commercial date can accommodate a timeline of its own with only minimal impacts on the implementation schedules of the remaining services.

During the transition from today's AS set to the future AS set, there may be the need for a Supplemental Reserve Service that would be similar to today's 30-minute Non-Spin Service. The details of a Supplemental Reserve Service will be determined as part of the transition plan.

Lastly, in addition to addressing the PFR/FFR substitution issue, ERCOT proposes that the discussions of the new AS include the concept of price ranking and substitution among the appropriate AS. Enforcing relative price rules for $MCPC_{FFR/PFR}$ greater than the $MCPC_{RR}$ greater than the $MCPC_{CR}$ demonstrates the relative value of each service in the ERCOT system and will help quantify pricing rules when the capacity reserves for each service are compromised by system-wide events. Such rules can be enforced by use of submission criteria and validation or within the DAM optimization. Further study and review are needed to ascertain the cost and benefit of the concept and the methodology utilized to enforce relative value constraints.

12. Summary of the Proposed Ancillary Services

Name	**Synchronous Inertial Response (SIR) Service**
Purpose	• Maintain minimum rate of change of frequency (RoCoF) • Provide sufficient time for primary frequency response
Background	• High non-synchronous generation penetration can de-commit synchronous generators • Peaking units with smaller inertia can replace base units to support system variations • Low inertia will result in quicker frequency decay and lower frequency nadir during generator outage
Qualification	• Resource with synchronous rotating mass
Resource Limit	Quantity for the resource's inertia contribution is determined as: $H \cdot MVA$ where H is machine inertia constant in seconds, MVA is the machine's rated output capacity in mega-volt amperes, and the product H times MVA is the kinetic energy that can be provided by the synchronous machine during system imbalance
System Criteria	• Maintain appropriate RoCoF • Maintain minimum duration from point A to point C, Figure 2 • No triggering of UFLS with two STP units outage
Deployment	• Instantaneous and continuous self-deployment
Performance	• Inertia support is a natural characteristic of the synchronous machine and is independent of external control or pre-disturbance power production/consumption.
Quantity	• To be determined (study required) • This will only be procured for hours when there is a residual need
Market Service	• Potential need in the future.
Comments	• Monitor and project the trend of ERCOT system inertia response and RoCoF • Identify the minimum needs of system inertia and duration between points A and C, Figure 2, or the maximum possible penetration of non-synchronous generation in ERCOT • Conduct a survey and identify the generator's RoCoF tolerance capability in ERCOT • Identify if the need for SIR is locational or system-wide. • Investigate value of synthetic inertia from wind farms for system's SIR

Name	**Fast Frequency Response (FFR) Service**
Purpose	• Supplement to inertia response • Improve RoCoF after FFR deployment • Improve frequency nadir • Provide sufficient time for primary frequency response
Background	• High non-synchronous generation penetration can de-commit synchronous generators • Peaking units with smaller inertia can replace base units to support system variation • Low inertia will result in quicker frequency decay and lower frequency nadir during generator outage
Qualification	• Resources need to inject full responsibility within 30 cycles, and maintain for at least 10 minutes • Resources need to be equipped with high resolution recorders, for example, PMU.
Resource Limit	• The capacity that a resource can respond within 30 cycles and sustain for at least 10 minutes.
System Criteria	• Maintain a minimum of RoCoF • Maintain minimum duration from point A-C • No triggering of UFLS with two STP units outage
Deployment	• Self-deployment though controller or relay • Staged based on the defined trigger threshold that can be multi-stage deployment .
Performance	• Fully self-deployed within 30 cycles at specified frequency threshold • Sustained for at least10 minutes or recalled by ERCOT signal
Metric	• Resource needs to provide the deployment records to ERCOT • Resource needs to deploy a minimum of 95% or maximum of 110% of the awarded obligation within 30 cycles and sustained for at least 10 minutes. • Need to pass above 90% of the previous months' deployment or cannot have two consecutive failure performance if less than one deployment in a month.
Quantity	• A minimum of xx MW • Highly interdependent with the amount available for PFR
Market	• Yes, FFR needs to be implemented with PFR together
Comments	• Multi-stage deployment • FFR restoration period following deployment - (90 minutes) • Ensuring minimum participation from Load Resources • Identify the minimum and maximum quantity for this service. Currently, up to 1400 MW LRs in the RRS to provide FFR-like support. • Identify the relation between FFR and PFR. For example, if PFR is under procured, what's additional need from FFR and vice versa? • Technology-neutral requirements might be a challenge for this service.

	Frequency thresholds can be resource (or technology) specific. For example, LRs at 59.7 Hz and storage at 59.91 Hz in order to better utilize the resources' capability. • Investigate if ERCOT needs FFR DOWN Reserve in future or not

Name	**Primary Frequency Response (PFR) Service**
Purpose	• Arrest frequency decay and reset frequency close to 60Hz • Improve frequency nadir • Meet NERC BAL-003 (FRO)
Background	• ERCOT is required to meet NERC BAL-003 to avoid triggering UFLS with losing two largest units. The first stage for UFLS is currently set at 59.3 Hz.
Qualification	• Biennial Governor Tests
Resource Limit	• Capacity that can be deployed by Resources Governor's for 1% change in Frequency outside Governor Dead-band • How much PFR can be deployed by Governors for 1% change in Frequency outside the Governor Dead-band, will be based on median of actual performance of the Generation Resources and Controllable Load Resources in last three measurable events measured at B point and B+30 seconds point
System Criteria	• No triggering of UFLS with two STP units outage • Procure Resources directly
Deployment	• Self-deployment with proportional response
Performance/Metric	• Performance measured during Measurable Events at B point and B+30 point to calculate droop performance • Sustained continuously against frequency deviation
Quantity	• Depends on how much FFR is procured • Deployment of these reserves should not violate security constraints.
Market	• Yes, PFR needs to be implemented with FFR together
Comments	• A Governor with droop setting not to exceed 5% shall be in-service whenever the Generation Resource is providing energy to the ERCOT Transmission Grid. All the Resources with PFR Obligation shall have the Governor Dead-Band no greater than +/- 0.036 Hz. As a concept, a Resource without a PFR Obligation can have the Governor Dead-Band bigger than what is required for Generators that are providing PFR so that these Generators are not required to provide PFR during normal frequency excursions. • Investigate pay for performance metric.

Name	**Regulating Reserve (RR) Service**
Purpose	• Match generation and demand between SCED interval • To restore the PFR reserve • Meet NERC BAL-001 (CPS1)
Background	• RR is needed to correct short-term power imbalance between each SCED interval • There is RR-Up and RR-Down
Qualification	• Resources can continuously receive and follow ERCOT Load Frequency Control (LFC) signal
Resource Limit	• min(NURR, NDRR)*5*0.7, • where NURR and NDRR are Normal-Up Ramp Rate and Normal-Down Ramp Rate
System Criteria	• Procure enough capacity to correct net-load variations and short term load forecast error • Procure Resources directly
Deployment	• Following ERCOT LFC signal
Performance	• Recommend new performance metric that grades resources based on their ability to closely follow ERCOT LFC signal (similar to PJM). • Resources providing RR service must be able to deliver and sustain the reserve deployments for up to 10 minutes. ERCOT will have to re-visit its LFC and RLC in order to minimize deployments of RR for more than 10 continuous minutes in one direction during normal operation.
Metric	• To be designed around performance requirement
Quantity	• net load variability, • short-term load forecast error • probability of extreme changes such as weather as applicable
Market	• Yes, for both UP and DOWN • Deployment of these reserves should not violate security constraints.
Comments	• Deployments to Resources directly • Deployment of these reserves should not violate security constraints. • To maximize the benefits of Resource with different characteristics, ERCOT should consider using different LFC signals • Investigate different performance metric that measures resources response accurately and explore the concept of pay for performance

Name	**Contingency Reserve (CR) Service**
Purpose	• To cover the largest single unit • To restore other AS reserve
Background	• CR is need to restore the frequency back to pre-disturbance level within 10 minutes and restore PFR and Regulating Reserve
Qualification	• Resources should be qualified based on their ability to ramp within 10 minutes
Resource Limit	• Up to the level demonstrated during qualification testing
System Criteria	• To cover the loss of single largest unit per NERC BAL-002 • To restore PFR and Regulating Reserves • Deployment of these reserves should not violate security constraints.
Deployment	• SCED
Performance	• Resources providing CR must telemeter ramp-rates such that SCED can dispatch the full CRS capacity that the Resource is obligated within 10 minutes. • Resources must reach the 95% of the SCED BP within 10 minutes.
Metric	• Resources providing CR must telemeter ramp-rates such that SCED can dispatch the full CR capacity that the Resource is obligated within 10 minutes. • Resources must reach the 95% of the SCED BP within 10 minutes. • Failure to meet any requirement stated would result in disqualification from providing CR. • Once disqualified, the Resources can request for requalification any time after 30 days Resources providing CR must be able to deliver and sustain the reserve deployments for the full hour it is carrying that obligation.
Quantity	• Minimum of largest single unit
Market	• Yes
Comments	• QSGRS and Load Resources are expected to be eligible to provide this service • Deployment of these reserves should not violate security constraints. • ERCOT Operations will establish a process to identify and flag any need for additional capacity through RUC process (same concept as ERAT)

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