Supporting Documentation for Volume 1, Chapter 11

Ancillary Service Modeling

Ancillary services provide fast and flexible response to keep the supply system in balance. There are two major components to ancillary services: 1) regulating reserves and 2) contingent reserves. A description of these services is contained in Table 12-1. Regulating reserves are used under normal operating conditions to keep the energy supply system in balance at approximately 60 Hz by providing short burst up and down to keep the system in balance. Load following is considered to be the steady linear ramp between the start and end of each hour. Contingent reserves are the single largest contingent resource and are seldom drawn upon except under conditions when a large generator trips off-line.

Table 12-1 Definition of key ancillary services

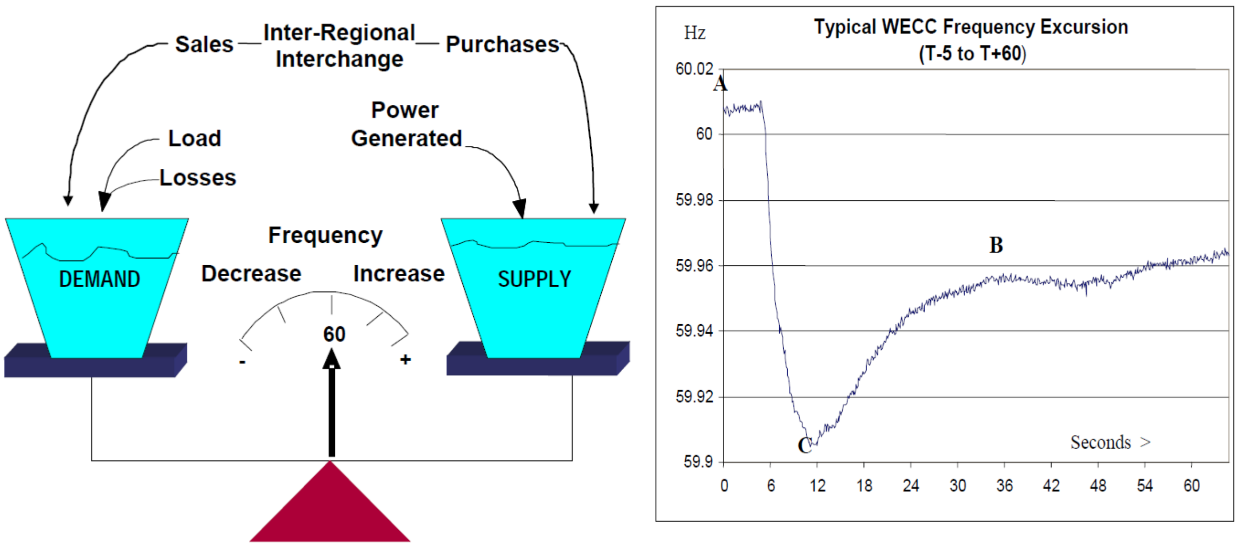
Service	Service Description		
	Response Speed	*Duration*	*Cycle Time*
Normal Conditions (used every minute of every day)			
Regulating Reserve	Online resources with automatic generation control (AGC) that can respond rapidly to system-operator requests for up and down movements; used to track minute-to-minute fluctuations in system load and to correct for unintended fluctuations in generator output to comply with Control Performance Standards (CPSs) 1 and 2 of the North American Electric Reliability Council (NERC 2006). System capabilities for meeting regulating reserves are approximately the 1 minute ramp up or down capabilities of the system.		
	~1 min	*Minutes*	*Minutes*
Load Following or Fast Energy Markets	Similar to regulations but slower. Bridges between the regulation service and the hourly energy markets.		
	~10 min	*10 min to hours*	*10 min to hours*
Contingency Conditions (used rarely, may be a couple times a year)			

Spinning Reserve	Online generation, synchronized to the grid that can increase output immediately in response to a major generator or transmission outage and can reach full output within 10 min to comply with NERC's Disturbance Control Standard (DCS). Used may be a couple times a year.		
	Seconds to <10 min	*10 to 60 min*	*Hours to Days*
Non-Spinning Reserve or Supplemental Reserve	Same as spinning reserve, but need not respond immediately; resources can be offline but still must be capable of reaching full output within the required 10 min.		
	<10 min	*10 to 60 min*	*Hours to Days*
Replacement	Same as supplemental reserve, but with a 30-60 min response time; used to restore spinning and non-spinning reserves to their pre-contingency status.		
	<30 min	*1 hours*	*Hours to Days*

Ancillary services are distinguished by the response time and duration over which they operate. Regulation and load following continuously balance generation and load under "normal" conditions. Regulation operates for short durations to capture small minute by minute variations in load. Spinning reserves, non-spinning (supplemental) and replacement reserves are slower acting reserves to sustain power output in case of a contingency event such as an unexpected plant outage.

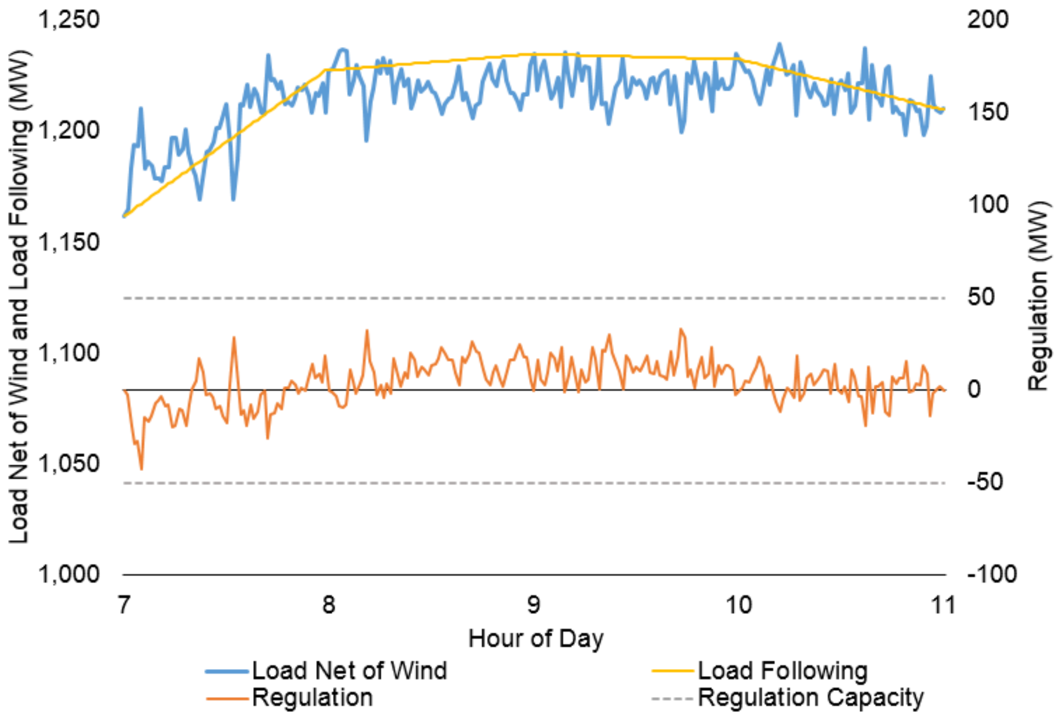
The objective for a balancing authority is to keep the system in balance at 60 Hz by continuously maintaining and balancing generation and load. The left side of Figure 12-1 illustrates the balance of supply and demand to keep the system at 60 Hz frequency. The right side shows the frequency hovering above and below around 60 Hz target as supply and demand vary (point A). As illustrated, for the first six seconds, the frequency is above 60 Hz. Over the next six seconds, an increase in demand causes the frequency to drop to 59.9 Hz (point C). The system responds to the drop in frequency by adding supply. Supply and demand imbalance improves over the remainder of the minute and the frequency rises back toward 60 Hz (point B). The fast response of supply to maintain system frequency is called regulation.

Figure 12-1. Illustration of frequency and supply and demand balance



Regulation helps to maintain interconnection frequency, manage differences between actual and scheduled power flows, and match generation to load. Figure 12-2 illustrates the difference between regulation and load following services. The morning ramp from 1,155 MW to 1,250 MW is primarily served through load following and base energy and is the linear ramp between hours designated by the yellow line. Regulation is shown by the small deviations and is designated by the blue line, which varies around the yellow line. Regulation uses generators equipped with automatic generation control (or AGC) to quickly change output, on the order of megawatts per minute (MW/min), to correct for moment-to-moment fluctuations in customer loads and generation; particularly variations in generation of intermittent renewable resources. Regulation (right side scale) required is shown by the orange line and varies between positive and negative, netting to zero over the course of several hours.

Figure 12-2. Illustration of regulation compared to load following



The characteristics of regulation and load following services are summarized in Table 12-2.

Table 12-2. Comparison of regulation and load following characteristics

	Regulation	Load following
Patterns	Random and uncorrelated	Highly correlated
Control	Requires AGC	Can be manual
Maximum swing	Small	10-20 times regulation
Ramp rated (MW/min)	5-10 times load following	Slow
Sign changes per unit	20-50 times load following	Few

Distinguishing between regulation and energy provides the framework for assessing the economic value of ancillary generation. Operators utilize regulation to maintain the system based limiting Area Control Error ("ACE"). ACE determines how much the balancing area is in imbalance with its generation and load. Positive ACE means the balancing area is over-generating and a negative ACE means it is under-generating. Because NorthWestern is part of a larger interconnected transmission system, it also needs to account for tie-line bias controls determined based on Equation (1).

$$ACE = NI_A - NI_S - 10B(F_A - F_S) \qquad (1)$$

Where NI_A is the actual net interchange with the neighboring balancing areas, NI_S is the scheduled net interchange, B is the frequency bias, F_A is the actual frequency, and F_S is the scheduled frequency. The net interchange is the sum of all the interchanges of a balancing area out of (+) and into (-) the area. If the actual net interchange is greater than the scheduled net interchange, the balancing area is over-generating. The second part of the equation [$- 10B(F_A - F_S)$] is introduced to ensure that systems are providing frequency response, and that the AGC control does not counter its frequency response obligation. The frequency bias, B, is a constant, with the units of MW/0.1Hz, that represents the amount of frequency response or regulation capabilities that the balancing area has, or should have. NERC has developed a scoring system for balancing authorities like NorthWestern that aggregates ACE values over the course of a month. The averaging of ACE values are traditionally measured through NERC Control Performance Standard 2 ("CPS2") scores, which need to be within 90 over the course of a month. In addition to satisfying the NERC CPS2 requirements for regulating services, NorthWestern must also meet the WECC ancillary service requirements. Within a 15-minute horizon, WECC requirements for ancillary services of spin and non-spin are superseded by the requirement to maintain CPS2 (i.e., spin and non-spin generation can be utilized to cover contingency events, but are assumed to equilibrate to WECC standards after 15 minutes).

The calculation of ACE and CPS2 is performed in PowerSimm to verify the level of regulation services provided are consistent with system needs. The results of minutely level dispatch substantiate system needs for the regulation, and calculates the cost of meeting regulation requirements.

System operations are measured down to minutely level generation and load with determination of ancillary service components of regulating reserves and contingent reserves as a function of intermittent renewable generation levels. The more granular dispatch conditions enable the physical system modeling to reflect actual system operations chronologically through time.