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October 2, 2008

Filing Center
Oregon Public Utility Commission
550 Capitol Street NE, Suite 215
Salem, OR 97301-2551

Re: **UM 1355: Investigation into Forecasting Forced Outage Rates for Electric Generating Units (OPUC Order No. 07-015)**

The schedule established in this docket calls for parties to circulate their positions and proposals by October 2, 2008. PGE has prepared a document that discusses our positions on various aspects of forecasting forced outage rates and our proposal to continue use of the existing four-year average methodology. This document and a one-page executive summary are attached.

If you have questions concerning the attached documents, please contact Patrick Hager at (503) 464-7580.

Sincerely,

Patrick G. Hager
Manager, Regulatory Affairs

Attachment

Cc: Kelcey Brown (OPUC)
UM 1355 Service List

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UM 1355
Attachment

PGE Proposed Forced Outage Rate Calculation Methodology

PGE Proposed Forced Outage Rate Calculation Method

PGE proposes that the four-year average methodology used in the most recent rate cases continue to be used in Oregon rate-making. The four-year-average approach to calculating and applying a forced outage rate ("FOR") in rate-making is reasonable, has served PGE and its customers well over many years, and should be continued. The existing methodology was documented in the "1984 Staff Memo" and PGE suggests that the Commission might consider having a contemporary memo drafted that would take note of the practice of the last 24 years, offer some additional explanatory description of the rationale for the methodology, and place the four-year-average method in a current context, perhaps including some recent examples.

PGE believes that the basic principle of *forecasting* is a critical concept in considering any FOR calculation method to be used for setting rates and that the Commission should recognize that principle explicitly for FORs. In that role, FOR calculation should aim to *forecast* the FOR that will be experienced during the same test period for which the filing utility projects cost and load for calculating rates. Issues relating to appropriate maintenance practices and cost should be dealt with explicitly in regulatory proceedings, not through the intermediary and noisy filter of FORs. The same is true regarding questions of utility prudence in plant management.

As in any good forecast, accuracy and precision are desirable FOR forecast qualities, and thus the bias, if any, and the error variance of a FOR forecasting method are important measures of the method's acceptability for rate-making. It is expected that the FOR of a prudently operated and maintained power plant alternately increases and decreases over the normal life of the plant, with the fluctuations lasting on the order of a few years. Thus an accurate forecast of FOR in a period lasting a year or two starting in the near future should reflect experience close in time to be accurate. And within the accuracy constraint the forecast should be based on enough data to allow a forecast of acceptable precision. Four years of data is adequate to strike a reasonable balance between these somewhat competing objectives, and also encompasses usual planned maintenance cycles and their effects, contributing a normalizing influence to the resulting forecasts. Good forecasting practices, leading to accurate and precise estimates, are also necessary for sound rate-making because they ensure that costs are effectively allocated to the customers who enjoy or influence the results of coincident system operations. It is noteworthy that the PCAM mechanism should reduce the effects of unavoidable FOR forecast errors by accommodating random fluctuations normally experienced in forced outages.

PGE presents here some basic FOR concepts, some observations regarding the actual empirical behavior of FORs over the life of a normal prudently operated generating plant, a description of some details involved in the practical acquisition of data used to calculate FORs, a brief review of the methods used in that calculation.

Forced Outage Rates – Basic Concepts

General Notions

The term, "forced outage rate" (FOR) can be used in any of several ways; for example:

1. As a *statistic*, a *random variable* that arises as a function of observable random phenomena associated with the operation of an electric generating plant, a FOR is *calculated* from measured values of other observed phenomena, namely performance events recorded during the attempted operation of the relevant generating plant. In this sense FORs are *statistics*[1], i.e. simple functions of a set of sample observations of a random variable.

2. As a *parameter* of a stochastic process a FOR can describe a combination of the frequency and duration of forced outage events. The particular probability model used affects how a FOR value translates into the specific behavior of the relevant random variables. FORs of this sort are not themselves directly observable, but they can be estimated and forecasted, perhaps using a *statistic* as in item 1 above.

3. As a *rate-making ingredient*, a value for FOR of a particular generating plant is used to determine the amount of energy produced by the plant during a test period; and by implication, the amount of acquisition of energy to make up for a loss of generation from the particular plant. Such make-up energy is often assumed to be purchased in an electric power market, and the cost of the make-up energy is taken to be a forecast of the price of energy in the relevant market.

FORs can be usefully viewed as an aspect of *reliability theory*, used as an expedient way to represent the failure performance of a plant. Different methods of FOR calculation have different practical and statistical properties, and the use of FORs in applications will have practical use and consequences that depend on those properties. For example, excluding unusual events - by some specific operational definition – from calculation of a FOR statistic used in rate-making seems at first glance to be desirable in pursuing the objective of reducing uncertainty, in the form of variability, of the resulting FOR. This is an example of a general class of robust statistical procedures that exclude so-called *outliers* from calculations. Such exclusion may yield statistics with desirable properties, but undesirable effects may also occur, including increased uncertainty of an estimator, and bias.

[1] "A function of one or more random variables that does not depend upon any *unknown* parameter is called a *statistic.*" Hogg and Craig, *Introduction to Mathematical Statistics,* Fifth Edition, Prentice Hall, pg. 156 (1995).

FORs are a shorthand compilation of more complex phenomena. The primary simplifying concept is that a plant is always in one of four states; up and running, down for planned maintenance, down because of some system problem, or shut down for economic reasons. Reduced to the simplest example, the calculation of an observed FOR consists of counting the number of hours that a plant is down because of a system problem, counting the number of hours that a plant is up, and forming the ratio of the former to the sum of the two, and disregarding both planned maintenance hours and economic shutdown hours; that is:[2]

$$\text{(I)} \qquad FOR = \frac{count\ of\ hours\ down\ for\ some\ system\ problem}{count\ of\ hours\ down\ for\ some\ system\ problem + count\ of\ hours\ up}$$

A Model And A Numerical Example

Equation (I) ignores hours for planned maintenance and economic shutdown, leaving just two system states to consider, up or down because of system problems. In basic reliability theory, these two states are often modeled as consecutive and alternating observations from two separate stochastic processes, one generating sequential durations of continuous up time before failure, and another generating sequential durations of continuous time undergoing repair. The time up between repair periods is sometimes modeled as an observation from a gamma-distributed[3] random variable, with each consecutive time up observed independently from the last. Time to repair may also be modeled as a gamma-distributed random variable, usually with different parameters. Given these assumptions, the FOR can be shown to follow a beta probability distribution.

Consider an example in which the expected duration of outages will be about 23 days and the time between outages will be about 342 days (remember, we will ignore planned maintenance for this example). Then the duration of up time between forced outages in years can be modeled as gamma(30,1) and the duration of outages, i.e. time to recover from a forced outage, is distributed as gamma(2,1). Then the FOR will be distributed as a beta random variable with

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[2] Actual calculation of FORs is more complicated and real plant operation more nuanced than this; there is some additional discussion later in this proposal.

[3] The gamma distribution arises naturally in reliability theory because it is the distribution of the sum of random variables that each independently follow an exponential distribution. The exponential distribution often does a good job of describing the life span of simple devices, e.g. light bulbs. If a complex device, like a power plant, is composed of a lot of simple devices that fail after time periods that follow an exponential probability distribution, and if the complex system can sustain up to some fixed number, n, of component failures before itself failing, then the time that passes before the system fails can be shown to be equal to the sum of n exponential random variables, and hence will have a gamma distribution.

parameters A = 2 and B = 30[4] because it is the ratio of outage duration to the sum of outage and up durations. Graphically, the probability density function of this example FOR is shown in Chart 1.

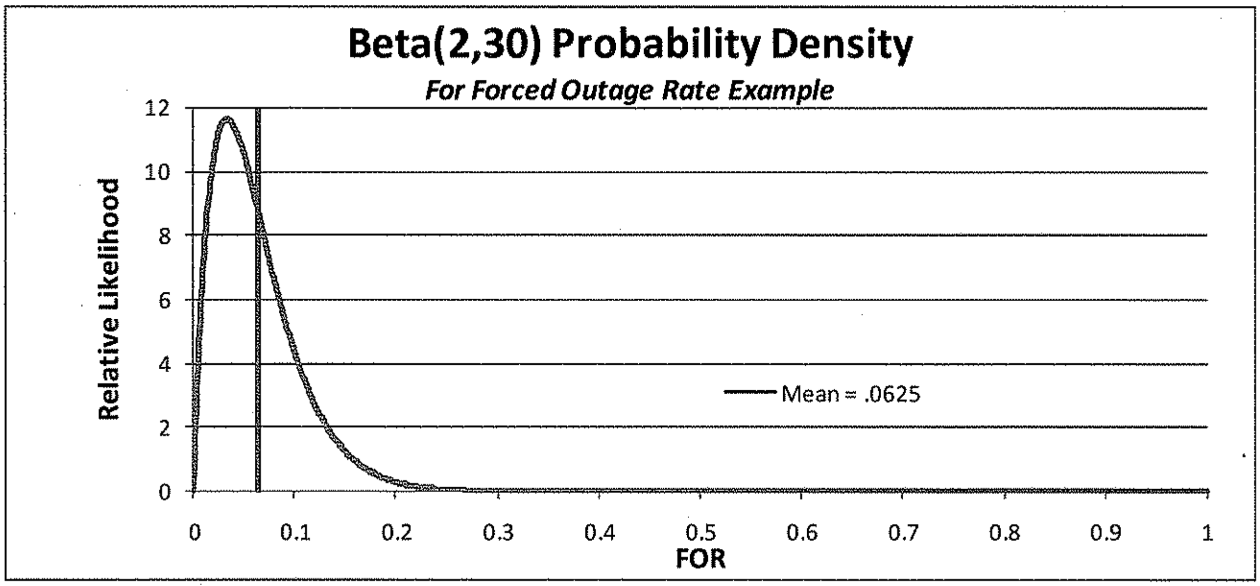

Chart 1

Given the probability distribution of observed FORs, the expected value of FOR, the distribution mean, seems a reasonable measure of what is meant by a "normalized" FOR that could be used in rate-making.[5] Generally, and for the example beta distribution, the average of a sample from the distribution has an expected value equal the mean of the distribution, that is, if $\{x_1, x_2, \ldots, x_n\}$ is a random sample from a beta(2, 30) distribution, then the expected value of the sample average is necessarily equal to the distribution mean.

Patterns Over Time

Forced outage rates reflect the reliability of large complex systems. Such systems often follow one of a relatively predictable set of reliability patterns over the course of their lives. One of the most common patterns is the so-called "bathtub curve." In the context of FORs, a bathtub curve

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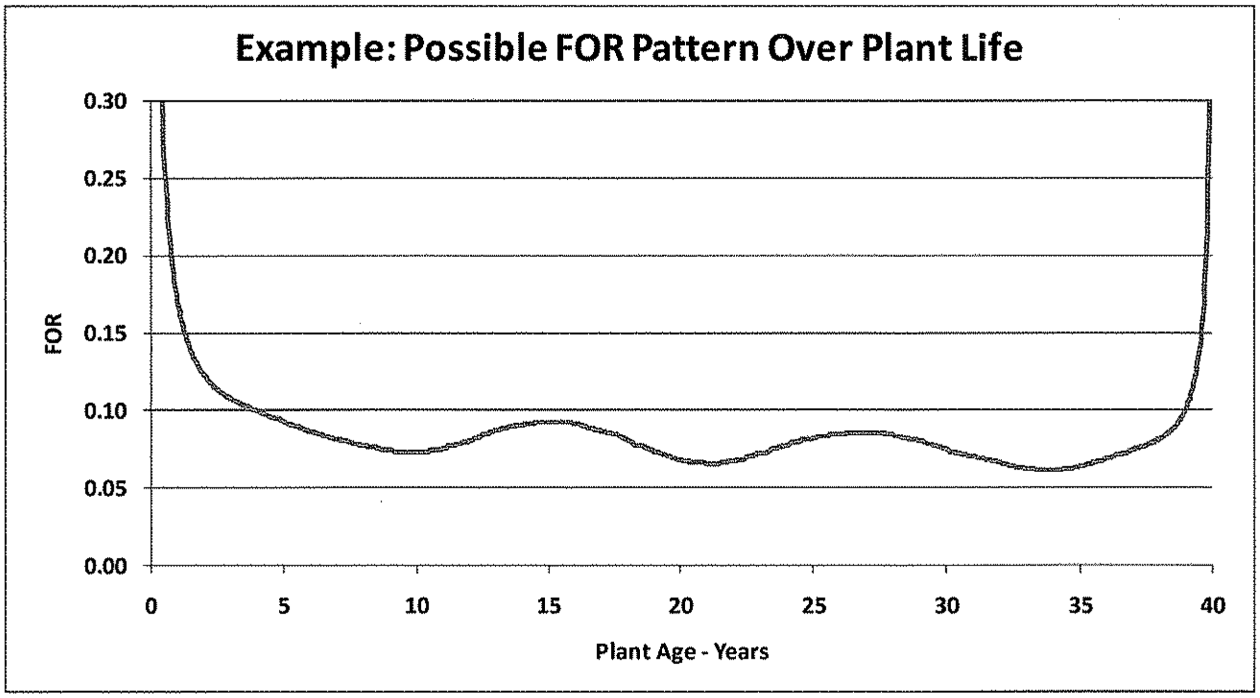
[4] For these gamma random variables the precise average outage and up times are approximately 22.8125 days and 342.188 days respectively.

[5] This also assumes that *forecasting* is the objective of FOR determination. In that case, the expected value of a random variable has many desirable properties as a target to be estimated and used as a forecast.

of FOR as a function of time simply implies that new plants experience relatively high rates of forced outage as a break-in period passes, then a long period of relatively constant FOR, and finally a relatively high and increasing FOR as the plant nears the very end of its useful life.

Some empirical evidence supports the intuitive notion that FORs move up and down over time as different plant subsystems age, are repaired or replaced, as various planned maintenance outage events occur, and possibly as a plant is run more or less intensely in response to economic influences. It may be reasonable to expect the FOR of a plant to rise, on a possibly long term average basis, as a plant ages. But careful attention to plant management and maintenance may also keep a plant running "like new" indefinitely, though perhaps with increasing cost over time. The implied tradeoffs represent one of the challenges of generating plant management. Also, similar plants can be operated in very different ways, and the wear and tear can be very different, depending on such conditions as, for example, location, regional load characteristics, weather, performance of other nearby plants, source and quality of fuel, fuel cost differences, and reasonable differences in management decisions. The following graph illustrates how FOR variation might occur for a prudently operated and maintained plant with a 40-year lifespan. In this example a somewhat cyclical variation in FOR is superimposed on a "bathtub curve" representing the pattern of FOR experienced by the plant during its life cycle. This is an "ideal" depiction of a FOR pattern and the actual realized FORs would vary in some random way around this pattern.



The time-varying nature of FORs argues for the use of good forecasts in rate-making. The forecasting approach to setting FORs for rate-making appropriately allocates to consumers costs that are expected to be incurred during the relevant test period.

Excluding Observations

It has been suggested that, to ensure a "normalized" estimate, some "extreme" or "unusual" data should be excluded from FOR calculations. This suggestion has a counterpart in the form of some so-called "robust" statistical procedures that exclude extreme observed values identified as "outliers." What effects would actually be experienced if the OPUC adopted such a practice? A suggestive answer is available in the context of the beta distribution example by examining the characteristics of the average FOR when some of the largest observed values are excluded from calculating the average FOR.

If the two largest of ten observations from the example beta distribution are excluded from the calculation of the average, the result is about 1½ percentage points lower than the true FOR, on average. The example true mean FOR was about 6.25%, so a practice of trimming the two largest values in calculating the average results in a bias downward of almost 25%. This does not speak well for the use of an upper trimmed mean estimator if accuracy is important. Under some assumptions trimming both ends of a distribution may make a statistic less uncertain, but this is not the case for distributions similar to the example beta distribution.

Some argument might be made for excluding the most dramatically unusual outage events from FOR calculations, but only if the likelihood of such an event can be clearly demonstrated to be outside all normal phenomena anticipated. For example, an act of war, or an extreme natural event like a disastrous earthquake. Questions of prudence are best addressed directly and not confused with the usual forecasting of FORs.

Some Characteristics Of Real Plant Operation And FORs

Real World Outage Phenomena

Contrary to the apparent assumption of the regulatory application of FORs in rate-making, power plants do not really run continuously at a constant reduced level of energy output reflecting a FOR "penalty," nor do they operate in an absolutely quantum manner, either all-on at full capacity or all-off. Rather, power plant output can reflect a mixture of both discrete and continuous sets of operating regimes. For example, power plants can suffer partial failures, operating at reduced output for some period of time. It is possible that repairs to subsystems might be conducted with the plant continuing to operate, eventually returning to full power without ever being completely shut down. There are numerous variations for performing calculations similar to equation (I) that accommodate a more nuanced measurement of plant performance, but for this general discussion equation (I) will be used to illustrate various points regarding FORs.

Outage rates are a virtual event, a calculated combination of the frequency, duration and character of both actual unplanned plant outages, the process of correcting and repairing the problems causing the outages, and the events that constitute the operation of a functional generating plant, including times when the plant is turned off for reasons other than maintenance. In the most obvious outage scenario, the plant is running, generating electric energy at full power, when the members of some set of plant components fail in some way, for some reason, and the plant consequently stops producing any energy and goes off-line. Repair efforts are then mounted by plant personnel, and after some period of time the failed components are fixed or replaced and the plant ramps quickly back to full power energy production. That state then continues until the next outage.

Real outages often follow a very different script with many possible surprises. Even during unconstrained operation, a plant may reduce power for many reasons unrelated to the plant's *ability* to generate full power. A plant will even sometimes safely and prudently generate more power than its rated capacity. However, partial outages are common. For example, some relatively small device may fail in a way that requires the plant to be run at reduced power while the device is being repaired, after which operation returns to normal. Special attention must be paid to how this and other *partial outages* are accommodated in the calculation of FORs.

FOR Data Collection Overview

Nature Of Raw Data

FORs are a calculated artifact created from measurements of other things; they are not directly observable. Generally, the basic raw material is logs of plant operation and the careful classification and counting of hours. Care is required because generating plants are not simply in one of two states, working or failed, operating or experiencing an outage. In some hours the plant runs normally and without constraints that are not of the operator's choosing; in other hours the plant is undergoing a session of maintenance planned and scheduled many months or even years in advance; in some hours a plant may be turned off because its power is not needed; in some hours a plant may be running, but with limited power output because of a problem with a system component; in some hours a plant may be deliberately turned off to fix a problem that had been noticed at an earlier time but that allowed the repair to be planned in advance; in some hours a plant will be turned off and unavailable because of an unexpected problem that must be fixed before operation can resume - an obvious forced outage.

These various classifications of hours in the life of a generating plant must be recorded by plant personnel, with noteworthy conditions written into plant logs. Analysts who calculate and forecast FORs must check these records and notes to make sure that any errors in classification have been corrected and that any apparent conflicts in different information sources are satisfactorily resolved.

FOR Calculations

Mechanics

FORs are easily calculated once the full classification of all plant hours is done. The crux of the computation is to first disregard any hours in which the plant was shut down deliberately, either for economic convenience (the plant's output is not needed because all load requirements are satisfied by other less expensive energy sources), or for a maintenance outage planned far in advance. The details of this calculation are fully discussed in the 1984 Staff Memo and in utility testimony over the years and up to the present time. Those details have not changed significantly from the clear exposition of the 1984 Staff Memo.

Other methods for calculating FORs have been discussed under the aegis of this Docket (UM 1355), but any alternative must be proven to be both a benefit to customers *and* fair to utilities' owners before being seriously considered by the Commission for use in rate-making. Further, the few if any incremental benefits resulting from a significant change in methodology are unlikely to exceed the burdens of vetting and implementing the change. The simple process invoked by the label, "four year average" belies the considerably more nuanced procedure actually used, which requires careful attention and skill to perform, and which results in a meaningful number useful in rate-making and consistent with the objectives of benefit to customers and fairness to utility owners.

The Commission and Staff have, in recent years, expressed increased interest in the *normalization* of forecasts used in rate-making. Simply put, *normalization* means that forecasts should be adjusted to account for the influence of variables that are expected to be different in a regulatory test period, compared with their behavior during the time period from which data was collected for preparing the relevant forecast. *Normalization* is appropriate if it improves the quality of the *forecasts* of the phenomena, essentially costs and loads, that influence rates and that are subject to myriad exogenous influences. Many of those influences are episodic or periodic in nature, and forecasts of costs and loads for a test period can sometimes be constructed to take the influencing phenomena into account, thus improving the accuracy and/or precision of the relevant forecast. The four-year-average method of forecasting FORs produces a forecast that is normalized across possible seasonal patterns of variation in outage phenomena. It is *normal* for outage events to vary in frequency and length over the life span of a prudently maintained generating plant. Thus *levelization* of outage rate forecasts is *not* normalization and would degrade the quality of the forecasts, i.e. would reduce forecast accuracy and precision. Also, as discussed earlier, omitting extreme historical observations from the calculation of a FOR forecast has an undesirable effect on the precision and accuracy of forecasts for reasonable distributions of FORs.

1984 Staff Memo Comments

Pages Five and Page Six of the 1984 Staff Memo show a brief discussion of one rationale for the selection of a four-year interval of data collection to support a FOR forecast. The argument reflects interest in a variety of normalization, specifically related to an expected four-year periodicity of planned outage lengths. PGE knows of no evidence that this general level of periodicity has changed, and notes that idiosyncratic differences in particular plants at particular times are unlikely to have significant effect on FOR forecasts based on four-year averages.

Shortcuts

Plants sometimes experience partial outages, problems with plant components that require power to be reduced, but that allow the plant to continue operation at the reduced power setting. The 1984 Staff Memo prescribes a practical computational method for dealing with partial outages that avoids the thorny problem of attempting to establish hourly values for "how much out" the plant was. The method is essentially a combination of two measurement conventions: the amount of outage is set as the relative power output during the outage, in comparison with the plant's maximum dependable capacity ("MDC"); and a linear interpolation across the hours after the outage as the plant returns to full power, between the amount of outage at the end of the outage and the MDC at the time the plant is back to full power.

UM 1355
Attachment

Executive Summary

Executive Summary: PGE Proposed Forced Outage Rate Calculation Method

PGE proposes that the four-year average methodology used in the most recent rate cases continue to be used in Oregon rate-making. The four-year-average approach is reasonable, has served PGE and its customers well over many years, and should be continued. The existing methodology was documented in the "1984 Staff Memo" and PGE suggests that the Commission might consider having a contemporary memo drafted that would update and more completely document the relevant theory and practice.

PGE believes that the basic principle of *forecasting* is a critical concept in considering any FOR calculation method to be used for setting rates and that the Commission should recognize that principle explicitly for FORs. Issues relating to appropriate maintenance practices and cost should be dealt with explicitly in regulatory proceedings, not through the intermediary and noisy filter of FORs. The same is true regarding questions of utility prudence in plant management.

As in any good forecast, accuracy and precision are desirable FOR forecast qualities, and thus the bias, if any, and the error variance of a FOR forecasting method are important measures of the method's acceptability for rate-making. Four years of data is adequate to strike a reasonable balance between these somewhat competing objectives, and also encompasses usual planned maintenance cycles and their effects, contributing a normalizing influence to the resulting forecasts, ensuring that costs are effectively allocated to the appropriate customers at the appropriate time. It is noteworthy that the PCAM mechanism should reduce the effects of unavoidable FOR forecast errors by accommodating random fluctuations normally experienced in forced outages.

PGE notes that elementary reliability theory supports the use of a simple average as a sound FOR forecasting statistic. Some fluctuation is normal, expected, and observed in even the smoothed forced outage rate of a prudently operated generating plant. It has been suggested that, to ensure a "normalized" estimate, some "extreme" or "unusual" data should be excluded from FOR calculations, but the normal effect of such exclusion would be, at best, a degradation of the precision of the forecast, and likely introduce bias in the forecast.

Considerable practical nuance is included in the four-year-average methodology of the 1984 Staff Memo, both explicit and implicit. Power plants do not really run continuously at a constant reduced level of energy output reflecting a FOR "penalty." Outage rates are a virtual event, a calculated combination of the frequency, duration and character of real outages that often follow a very different script with many possible surprises.

A significant change in methodology will incur the burdens of vetting and implementing change. The simple process invoked by the label, "four year average" belies the considerably more nuanced procedure actually used, which requires careful attention and skill to perform, and which results in a meaningful number useful in rate-making and consistent with the objectives of benefit to customers and fairness to utility owners. PGE has faithfully conducted this process and the periodic review of the Commission ensures that the benefits and fairness of the existing FOR forecasting methodology will continue.

CERTIFICATE OF SERVICE

I hereby certify that I have this day caused the foregoing **INVESTIGATION INTO FORECASTING FORCED OUTAGE RATES FOR ELECTRIC GENERATING UNITS** to be served by electronic mail to those parties whose email addresses appear on the attached service list, and by First Class US Mail, postage prepaid and properly addressed, to those parties on the attached service list who have not waived paper service from OPUC Docket No. UM 1355.

Dated at Portland, Oregon, this 2nd day of October 2008.

PATRICK G. HAGER

eDockets

Docket Summary *Return to Search Page* *eFilir*

Docket No: UM 1355 **Docket Name:** INVESTIGATION INTO FORECASTING FORCED OUTAGE RATES FOR ELECTRIC GENERATING UNITS

Print Sum

In the Matter of THE PUBLIC UTILITY COMMISSION OF OREGON Investigation into Forecasting Forced Outage Rates f Electric Generating Units. (See Order No. 07-015, Ordering paragraph 5.)

Filing Date: 11/2/2007

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Law Judge: ALLAN ARLOW **Phone:** (503) 378-3511

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