Leveling of Oil Fuel Prices Through Hedging Practices at the Puerto Rico Electric Power Authority

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ABSTRACT

Up to the present, all the discussions since mid 1980's regarding the convenience of leveling fuel costs have been developed on a qualitative basis. This paper will try to provide quantitative information for corporate decisions regarding the main concerns of (1)What is a convenient leveling oil fuel price level? and (2) What is the level of sales / revenues vs. oil prices at which the Bond Rating Agencies as well as the Authority should start giving considerations?

SINOPSIS

Todas las discusiones desde mediados de los años 80 hasta el presente acerca de la conveniencia de nivelar los costos de combustible han sido desarrolladas desde un punto de vista cualitativo. El presente artículo intentará proveer información cuantitativa para las decisiones corporativas que tienen que ver sobre: (1) ¿Cuál es el nivel más conveniente de nivelación del precio del combustible? y (2) ¿Cuál es el nivel de ventas / ingresos vs. precios de combustible que deben considerar, tanto las agencias de Bonos de Rentas así como la Autoridad de Energía Eléctrica?

I- INTRODUCTION

Hedging practices in this paper refer to counterbalancing actions for financial protection, in our case, protection from the up and downs of oil market prices by leveling oil prices. Leveling the price of oil through hedging mechanisms does not come free. There are a few alternatives that can be considered in leveling the oil fuel prices. Three of the most common are:

(1) Usually, a banking institution would enter into agreements to pay a certain amount per barrel of oil if the price of oil goes over a predefined high value. On the other hand, when the price of oil goes below a predefined low value, the Bank institution will collect a certain amount per barrel of oil.

(2) The second alternative is a variation of the first, in which the Authority serves as the banking institution. In this second mode, the Authority could establish a special "Oil Leveling Fund". Funds will be deposited in the Fund when the price of oil drops below a certain low value, and funds will be drawn from the Fund to help pay for part of the oil burned when the oil prices go above a certain high value. The Leveling Fund could be enriched from other sources of income, such as the development of other products or services related to electricity services in this new Era of Hi-Tech; and

(3) Diversification of electrical generation sources. New generation sources dependent on more stable priced fuels such as gas and coal can considerably level oil fuel prices. The Authority has advanced considerably this last approach with the 500 MW Ecoeléctrica Gas Power Plant at Peñuelas and the 450 Mw AES Coal Power Plant at Guayama, Puerto Rico.

II- ANALYSIS

The present basic rate structure excludes fuel. The adjustments for fuel and private energy purchases are added in the consumer's bill.

The analysis begins by establishing an equation that expresses the net revenues of the Authority, which are oil fuel dependent. This dependent oil fuel net revenues are also strongly dependent on the amount of kilowatt-hour (KWhr) sales, as well as on the price of the oil fuel ($/Bbl). In the analysis, the initial oil fuel price is denominated P_0 and the initial KWhr sales are denominated K_0.

It can be readily observed from the net revenue equation that, if the sales are not affected, the net revenues increases if the oil fuel price increases and that they decrease if the oil fuel price decreases. *The main scope of the problem is to find how much drop we can permit in the KWhr sales without affecting the net revenues. Hedging of oil prices should then only be considered if the oil fuel dependent net revenues are affected negatively.*

To accomplish this, the mathematical derivative of the equation expressing net revenues with respect to oil price P is obtained. If the net revenue is not going to be affected by the oil price changes, then the change in net revenues with respect to P must be equal to zero. Then, the derivative is set equal to zero. A differential equation results. The equation is solved by separation of variables. A general solution is

$$\frac{K}{K_O}=\frac{a+P_O}{a+P}, \quad (1)$$

where a is a constant. The value of a depends on other system constants. These other system constants can increase to make a larger which, in turn, can result in making the sales less sensitive to oil fuel price variations.

It is shown that, excluding the case of incremental economic dispatch, that:

$$a=\frac{0.93\,HS}{(g-1)f}+\frac{HS\gamma}{E_i}\,\frac{1-f}{f} \quad (2)$$

where

H = KWhr sold per barrel of oil during a period.

S = average price (\$/KWhr) of energy sold during a period (basic rates).

f = fraction of KWhr sales taken up by the oil fuel based electric system.

$1-f$ = fraction of KWhr sales taken up by co-generators.

γ = Adjusting factor and Co-generator Power Contract Performance coefficient.

E_i = Transmission and Distribution system efficiency.

g = Tax factor and efficiency = $\frac{0.93}{0.89E_i}$. (by law, the 0.93 accounts for the 7% contribution to municipalities and the 0.89 accounts for the total contribution in lieu of taxes)

In the analysis, the fraction f is considered for the three main conditions:

1- no purchased generation, a historical fact
2- purchased generation without economic dispatch or fixed fraction f of the total generation
3- purchased generation with assumed economic dispatch, or variable f.

It can be observed from equation (2) that, for the case of power purchase approaching 100%, f approaches zero, the value of a becomes very large, P and P_O can be neglected in equation (1) and $\frac{K}{K_O}$ becomes a horizontal line passing through the point $\frac{K}{K_O}=1$. This makes the KWhr sales completely insensitive to oil fuel price variations. In essence, this is the result of not using oil fuel at all.

The case of incremental economic power dispatch involves the consideration of a variable fraction f (f is the fraction of load taken up by the oil based system), which depends on the cost of oil. It is shown in the analysis that, as the oil price increases, the co-generators take more share of the load, making hedging considerations less costly. This case is rather complex and it is the last case treated here.

In the absence of purchased power, the value for a is unity (1.00). Observe then, that for the case of no power purchase setting (that is, f = 1), the value of a in equation (2) is reduced to

$$a=\frac{0.93\,HS}{g-1} \quad (3)$$

III- FURTHER INTERPRETATION OF EQUATION (1)

The curve defined by equation (1) can be called the elasticity of the Authority's KWhr sales on net revenues with respect to oil fuel price variations. *As long as we operate above the curve defined by this equation, the net revenues of the Authority are affected by oil-price changes in a positive way. That is, the net revenues increase. If we operate below the curve the net revenues are affected in a negative way. That is, the net revenues decrease. Operating exactly on the curve results in no changes either positive nor negative in net revenues.* This is expressed in Figure 1, where the oil price is fixed at \$15/barrel before variations are considered and the typical values of the largest generating units of the Authority are used:

H = 493.8 KWhr/Bbl,

S = 0.0609 \$/KWhr,

E_i = 0.8375,

$$g-1=\frac{0.93}{0.89E_i}-1=0.2477,$$

$\gamma = 1.0$ and

$f = 0.8$

The equation (1) is different from the well known classical elasticity of demand in which the KWhr sales responds to price variations due to the attitude and habits of the people and their economic limitations. The classical elasticity of demand is very important and it means that as long as the classical elasticity of demand falls above the curve of equation (1), the economics are favorable. When the classical elasticity of demand falls below curve of equation (1), i.e. the KWhr sales have dropped to lower values than those set by equation (1), then it is time to perform some action to bring back the sales to within equation (1). In determining hedging values for oil prices, it is desirable, but not mandatory, to have available the classical curve of elasticity of demand. It is always a good planning tool.

The problem is somewhat more complex, because every time that a new origin $\left(\frac{K_O}{K}, P_O\right)$ is defined due to the dynamics of the oil price changes, a new curve parallel to the previous curve but moved to the right (for price increases) or moved to the left (for price reductions) comes into effect. This is shown in Figure 2 by several curves shown with different values of initial oil prices and two values of the oil fraction f.

In order to better understand the dynamics of the analysis, i.e. of a moving P_O, it would be convenient, although not necessary, to transform equation (1), assuming a fixed value of f. Solving for $\frac{P}{P_0}$ in terms of P_O with fixed ratio $\frac{K}{K_O}$ we have:

Let $\frac{K}{K_O} = Q$ (fixed value). Then,

$$\frac{P}{P_O} = \left[\frac{1-Q}{Q}\right]\frac{a}{P_O} + \frac{1}{Q} \qquad (4)$$

Suppose that, for the cases covered by equation (1), we are able to define a value for the reduction in KWhr sales at which we want to start considering hedging. Lets assume that this value is 5%. We do not want the sales ratio Q to go down below 0.95. The first thing is that we must define the level of operation. What is the price of oil to begin with? If it is \$1.80 per barrel (as it was around 1966), we surely can permit a very large increase in the price of fuel before net

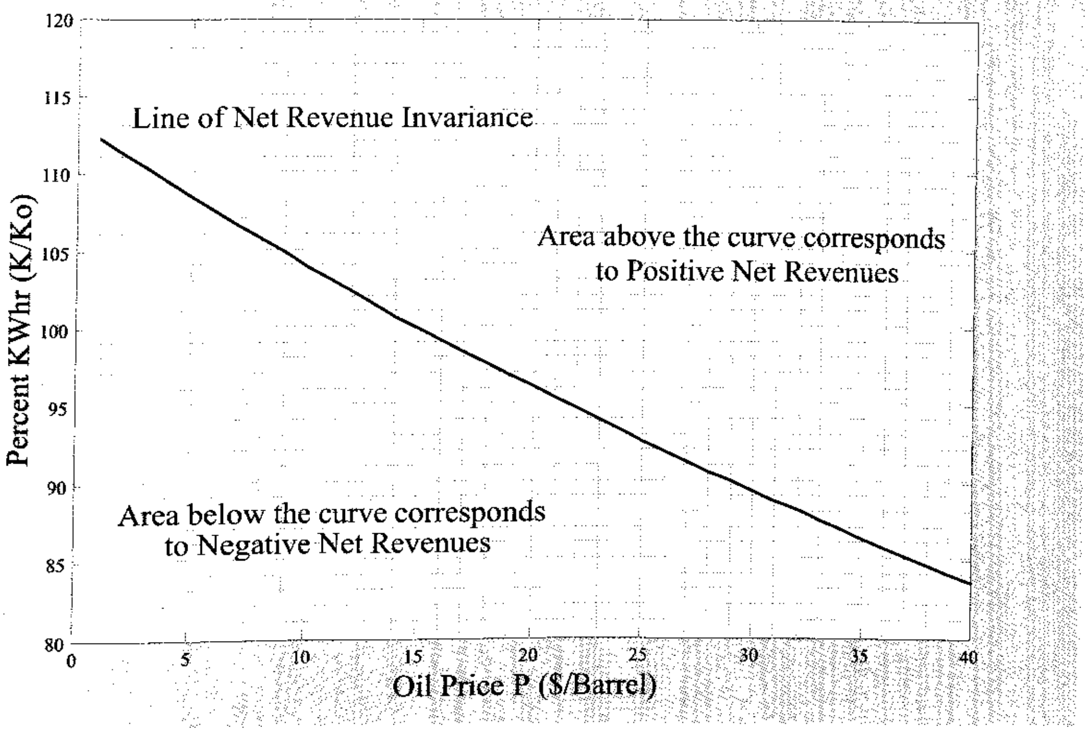

Figure 1: *Percent KWhr Sales vs Fuel Oil Price*
Net Revenue Invariance ($f = 1$, $P_O = 15$)

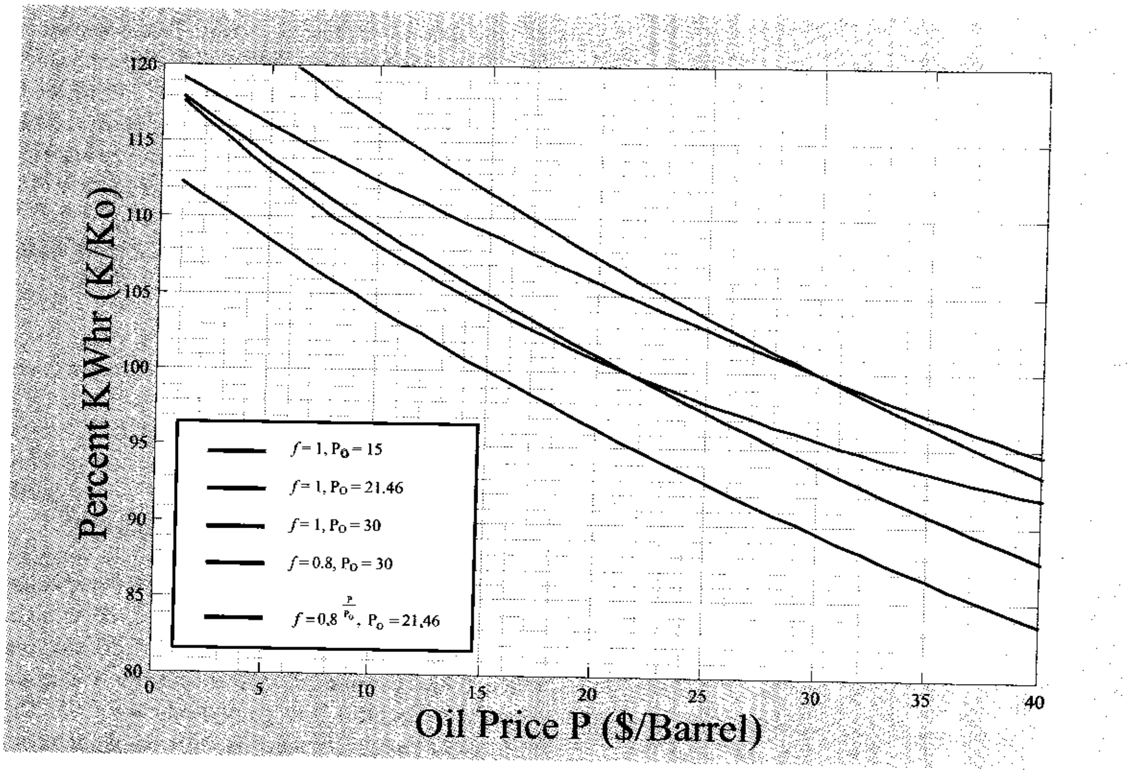

Figure 2: Percent KWhr Sales vs Fuel Oil Price Net Revenue Invariance

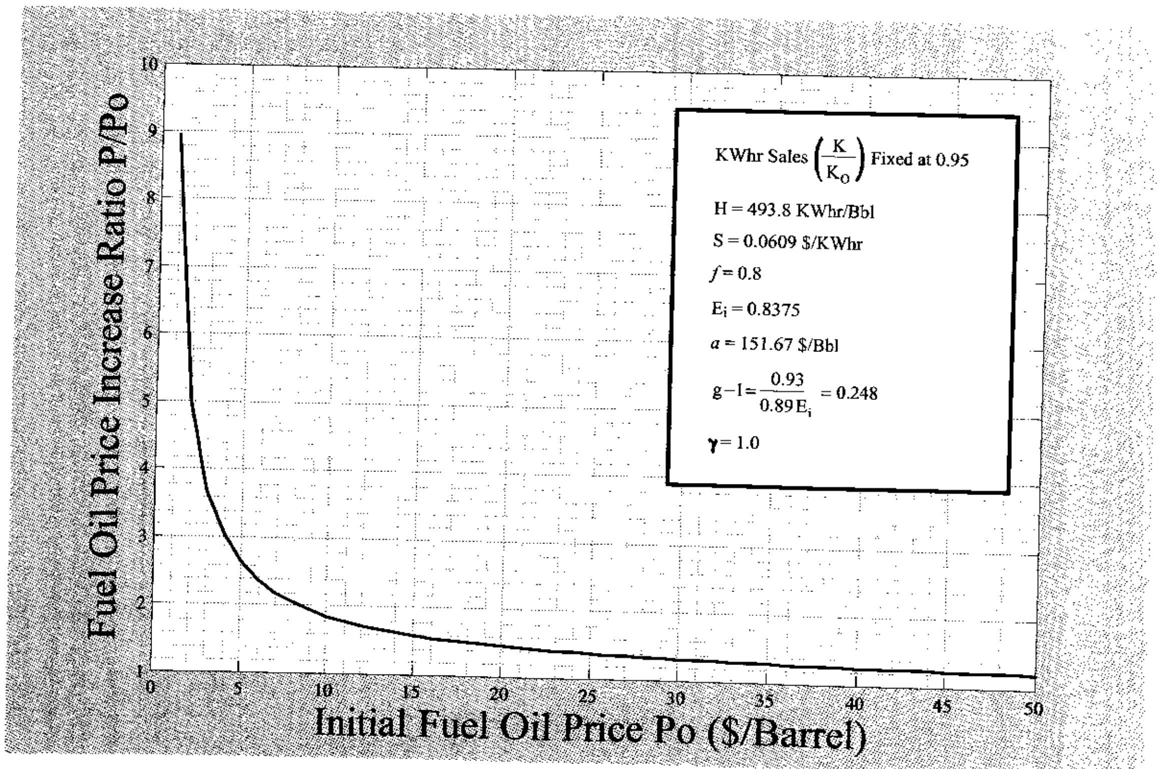

Figure 3: Initial Fuel Oil Price vs Fuel Oil Price Increase Ratio For 5% KWhr Fix Sales Decrease and Invariant Net Revenues

revenue economics are affected.

We now let Q = 0.95. For the case of fixed fraction, let $f = 0.8$,

$$a = \frac{0.93\,HS}{(g-1)f} + \frac{HS\gamma}{E_i}\,\frac{1-f}{f} \qquad (2)$$

Substituting typical values into (2), we get

$$a = 151.67 \text{ \$/Bbl}$$

Substituting into (4) we get

$$\frac{P}{P_O} = \frac{7.98}{P_O} + 1.053 \qquad (5)$$

The graph of equation (5) is shown plotted in Figure 3.

Suppose that we are operating with a price of oil (P_O) of \$5/Bbl. From Figure 3 we can read at this value of P_O that we can stand an oil price increase of 2.65 (or 265%) corresponding to \$13.25/Bbl before the sales are reduced approximately down to the neighborhood of 95%. Under this conditions, hedging must begin just above \$13.25/Bbl if we desire not to permit net revenues to go negative or to the area below the curve.

If the price of oil reaches \$15.25/Bbl under this scenario. then for full hedging you must disburse from the Hedging Funds a \$2/bbl. This, multiplied by the total barrels (approximately 0.80 x 35 million barrels), equals to \$56 millions for full hedging.

On the other hand, suppose that we are operating with an oil price of \$21.46/Bbl (PREPA 1999 FY value).

From the graph of Figure 3 we can read that we can permit an increase in oil price of 1.43 (143%) or up to \$30.69/bbl before we reach the neighborhood of 95% in sales. For full hedging, then, we must assign the difference of \$9.23/Bbl times 80% times 35 million barrels, or \$258.4 millions.

When oil prices decrease, a reverse condition holds. Funds can be deposited into the leveling fund when sales exceed 105%. Equation (1) has to be solved for $\frac{P_O}{P}$ (P_O greater than P) with Q=1.05. The plot of P vs. $\frac{P_O}{P}$ is then made.

Unless hedging is accomplished by the substitution of oil fuel by more stable fuel alternatives, the hedging costs involved are very high. If no such fuel substitution alternative is possible, then the other alternatives for maintaining a healthy economical condition are: rate increases, modification of applicable Tax laws, and/or significant reduction of other non-oil fuel related expenses such as personnel reduction by attrition, personnel retraining and education for the use of more effective and productive tools and advanced technologies. Back in the last decade, oil price increases over 1000% were experienced and it seems that they are going to continue.

Graphs similar to figures shown should be prepared for adequate planning purposes using different values of the parameters involved. The figures shown do not apply to economic dispatch, but the correct relationship for economic dispatch case (variable f) is the last case considered here.

IV- MATHEMATICAL ANALYSIS

Three cases will be discussed:

1- No purchased generation.
2- Purchased generation, fixed fraction f.
3- Purchased generation with variable fraction f, the case of economic dispatch.

Following is the list of variables and constant used in the analysis of the cases. Let:

B = Number of oil fuel barrels burned in a specified period.

B_O = For the cases of power purchase, this is the number of oil fuel barrels that would be used if there were no power purchase.

H = KWhr sold per barrel of oil burned resulting from Authority owned Power Plants.

P = Average price of oil mix used in the specified period, including all costs.

K = KWhr sold in the year.

S = Average price (\$/KWhr) of energy sold during the period, excluding all fuel and purchased energy costs (basic rate).

V = Total dollars payment per period to Vendors of electric energy in qualified facilities.

g = A factor which accounts for taxes and electric transmission and distribution efficiency. Actual rate structure at PREPA consists of a contribution in lieu of taxes of 11% of all sales of which 7% is paid to municipalities and 4% is retained by the Authority for Corporate government assigned purposes.

R_n = Net dollar revenues of the Authority for a specified period.

F = Fuel adjustment recovery factor unit cost in \$/KWhr.

W = Energy purchased adjustment recovery factor unit cost in \$/KWhr.

E_i = Electric efficiency of the transmission and distribution system.

f = Fraction of the total KWhr generation taken up by co-generators.

γ = Co-generators Power performance coefficient or KWhr unit cost adjustment factor.

Q = Fixed ratio for energy sales.

The Net Oil Fuel dependent Revenues of the Authority is equal to the Oil Fuel Dependent Income less the Oil Fuel Dependent Expenses.

A- Oil Fuel Dependent Income per KWhr Sold

1- Sales from Basic Rates:

$$S \tag{6a}$$

2- Oil Fuel Adjustment:

$$F = \frac{PB}{0.89\,K\,E_i} \tag{6b}$$

3- Purchased Energy:

$$W = \frac{V}{0.89\,K\,E_i} \tag{6c}$$

B- Oil Fuel Dependent Total Expenses and Net Revenues

1- Payment for oil fuel burned:

$$PB \tag{6d}$$

2- Payment for Energy Purchased:

$$V \tag{6e}$$

3- Payment to Municipalities:

$$0.07K(S + F + W) \tag{6f}$$

Oil fuel Dependent Net Income R_n:

$$R_n = K(S+F+W) - 0.07\,K\,(S+F+W) - PB - V \tag{6}$$

The factor 0.07 is the tax payment to municipalities. The balance from the 11% total State contribution in lieu of taxes is retained by the Authority for Corporate purposes.

Substituting equations (6a) through (6f) into (6) and combining terms get

$$R_n = 0.93KS + (g - 1)\,PB + (g - 1)\,V \tag{7}$$

where

$$g = \frac{0.93}{0.89\,E_i} \tag{8}$$

Other Income and Expenses are insensitive or nearly insensitive to Fuel costs.

We will analyze first the case where V=0 or no power purchased.

C- Power Generation Scenario

1- Case V= 0

Substituting in equation (7) for the number of barrels

$$B = \frac{K}{H} \tag{9}$$

we get

$$R_n = 0.93\,K\,S + (g-1)\frac{K\,P}{H} \tag{10}$$

We are interested in finding the invariance of the net revenues, R_n, with respect to oil fuel price variations. Hence, let us get the derivative of R_n with respect to P.

The value of S, the price of the KWhr, remains fairly constant because it excludes fuel costs and depends on established basic rates. Hence,

$$\frac{dR_n}{dP} = 0.93S\frac{dK}{dP} + \left[\frac{(g-1)}{H}\right]\left[K + P\frac{dK}{dP}\right] \tag{11}$$

The value at which R_n, the Authority net revenues remains unchanged with either increasing or decreasing oil fuel prices, is obtained by setting its derivative $\frac{dR_n}{dP}$ equal to zero. Hence,

$$0.93S\frac{dK}{dP}+\left[\frac{(g-1)}{H}\right]\left[K+P\frac{dK}{dP}\right]=0 \qquad (12)$$

Rearranging equation (12), making a "friendly" multiplication by $\frac{dP}{K}$ and "friendly cancellations", separating variables, and letting

$$a=\frac{0.93SH}{(g-1)} \qquad (13)$$

we get,

$$\frac{dK}{K}+\frac{dP}{(a+P)}=0 \qquad (14)$$

Integrating above equation, we obtain,

$$\ln K + \ln (a + P) = \ln C \qquad (15)$$

where C is the constant of integration. Rearranging,

$$a+P=\frac{C}{K} \qquad (16)$$

The constant of integration, C is evaluated from the original conditions before oil price changes.

Substituting $K=K_O$ and $P=P_O$ and rearranging, we obtain,

$$\frac{K}{K_O}=\frac{a+P_O}{a+P} \qquad (17)$$

2- *Interpretation of Equation (17)*

Equation (17) indicates that, beginning from the starting point (K_O, P_O), the KWhr sales responds to an inverse function of the oil fuel prices and that, provided that the economics are maintained within this inverse function curve, the net revenues will not be affected; they are invariant to oil fuel price variations. The net revenues are not affected by either increasing or decreasing oil fuel costs. In simpler words, the equation indicates quantitatively the amount of energy sales reduction due to increased oil fuel price that can be experienced without affecting net revenues. It is a quantitative expression for the elasticity of the KWhr sales vs. oil price with invariability of net revenues.

Operation below the curve implies the reduction of the net revenues, and this should be avoided.

Operation above the curve implies the increase in net revenues, a positive condition.

3- *Application of Derived Equation (18)*

Using the same values stated for the evaluation of equation (5), we can evaluate the relationship given by equation (17). The corresponding curve is shown in Figure 1. The value of P_O used for plotting the curve corresponds to that value P_O at which $\frac{K}{K_O}$ is 1.0.

We will now proceed to analyze Case II, which includes energy purchases.

D- Power Generation Scenario with Fixed Purchase

1- Case $V \neq 0, f$ fixed

Repeating equation (7) for the Authority net revenues,

$$R_n = 0.93KS +(g-1) PB +(g-1) V \qquad (18)$$

Setting $B=\frac{K}{H}$,

$$\frac{dR_n}{dP}=0.93S\frac{dK}{dP}+\left[\frac{(g-1)}{HV}\right]\left[P\frac{dK}{dP}\right]+ (g-1)\frac{K}{HV}+(g-1)\frac{dV}{dP}=0 \qquad (19)$$

The energy purchased, V, is dependent on the Power contract with the corresponding Energy Vendors. A fraction of the total energy sales must be assigned to Co-generators to satisfy the economics of the Power Contract. Let f be the fraction of the total energy sales that will be taken up by the Authority Power Plants, $(1 - f)$ the fraction to be taken up by the co-generators and the Power Contract performance coefficient. This coefficient will normally be equal to 1.00. However, under various conditions including either penalties or bonuses, the actual net payment to the co-generators might depart from what is normally expected or forecasted. The value of γ can also be used to adjust for the actual value of the unit price of KWhr coming out from the co-generators.

The total dollar power purchase is

$$V=S(1-f)\gamma\frac{K}{E_i} \qquad (20)$$

and

$$\frac{dV}{dP}=\frac{S(1-f)\gamma}{E_i}\frac{dK}{dP}-\frac{SK\gamma}{E_i}\frac{df}{dP} \qquad (21)$$

Substituting equation (21) into (19) and rearranging we get,

$$\left\{0.93S+(g-1)\frac{Pf}{H}+\frac{(g-1)}{E_i}S\gamma-\frac{(g-1)}{E_i}S\gamma f\right\}\frac{dK}{dP}+$$

$$(g-1)K\left[\frac{f}{H}+\left(\frac{P}{H}-\frac{S\gamma}{E_i}\right)\frac{df}{dP}\right]=0 \qquad (21b)$$

For this case, f = constant. Thus,

$$\frac{df}{dP}=0$$

Making a friendly multiplication by $\frac{dP}{K}$ and friendly cancellations, rearranging terms, and separating variables, we get,

$$\frac{dK}{K}=\frac{1}{a_V+P}dP \qquad (22)$$

where

$$a_V=\frac{0.93HS}{f(g-1)}+\frac{HS\gamma}{E_i}\frac{1-f}{f} \qquad (23)$$

Integrating both sides of equation (22) we get,

$$\ln K = -\ln(a_v+P)+\ln C \qquad (24)$$

where C is the constant of integration. To evaluate C, we use the initial conditions.

At $P=P_O$,

$$K=K_O. \qquad (25)$$

Then,

$$\frac{K}{K_O}=\frac{a_V+P_O}{a_V+K} \qquad (26)$$

Equation (26) is identical to equation (17). The difference between a and a_V results from the introduction of the fraction f. For f=1.0, $a_V = a$

Decreasing f increases the Co-generators loading, and increases the value of a. This will produce a function curve with a lower slope, which means a smaller elasticity of sales, and, therefore, less sensitive to oil price fluctuations.

2- Example Calculation

$$\frac{K}{K_O}=\frac{a_V+P_O}{a_V+P} \qquad (27)$$

Using the values quoted in Part III, a fraction f = 0.8 and a value of γ = 1.0, the value of a is 150.11. The corresponding curves are shown in Figure 1 for various values of P_O (the value at which $\frac{K}{K_O}$ is unity.)

The sensitivity of sales $\left(\frac{K}{K_O}\right)$ to the use of co-generation is evident.

As can be seen from Figure 1, the effect of changing P_O with f constant is to shift the curves to the right if the initial oil price increases and shift the curve to the left if the oil price decreases. This last movement permits higher percentage sales variations before net revenues are affected.

Observe also that increasing the value of f, i.e. increasing the Authority oil-based generation, makes the curves more steep or more sensitive to oil fuel price variations.

Hedging values can also be calculated by reading the percentage *sales drop* below the particular curve, multiplying by K_O to obtain the KWhr drop, divide by H to obtain the number of oil barrels and multiply by the price of the barrel to obtain the full hedging cost.

E- Power Generation Scenario
$V\neq 0, f\neq 0$

For this case, the first thing that is needed is to determine the relationship between the fraction f (power fraction share between the co-generators and the oil-fuel based electric system) and, then, use this relationship in the equation 21b.

For this, a series of studies of incremental power economic dispatch including all the contract limitations are required. A curve fitting of the data could then be made for use in equation 21b.

This data is not available at this moment, but various points of such a curve are known:

1– When oil fuel is very, very expensive, $f \to 0$
2– When oil fuel is free, f = 1.0

3– When the initial dispatch dictates f_o, $f = f_o$

4– When P increases, f should decrease and vice-versa

5– The value of f can never go negative nor greater than 1.0

The power function $f = f_O^{\frac{P}{P_O}}$ satisfies all the above conditions. Although this is not truly representative of economic dispatch, it is used as an approximation in the absence of any data at all.

So, let

$$f = f_O^{\frac{P}{P_O}} \qquad (28)$$

and

$$\frac{df}{dP} = f_O^{\frac{P}{P_O}} \left[\frac{\log f_O}{P_O} \right] \qquad (29)$$

Repeating equation 21b, we have,

$$\left\{ 0.93S + (g-1)\frac{Pf}{H} + \frac{(g-1)}{E_i} S\gamma - \frac{(g-1)}{E_i} S\gamma f \right\} \frac{dK}{dP} +$$

$$(g-1)K\left[\frac{f}{H} + \left(\frac{P}{H} - \frac{S\gamma}{E_i} \right) \frac{df}{dP} \right] = 0 \qquad (30)$$

Substituting for f and $\frac{df}{dP}$, equations (28) and (29) in equation (30), rearranging and separating variables, we have,

$$\frac{-\left[\frac{1}{H} + \frac{P}{H}\frac{\log f_O}{P_O} - S\gamma \frac{\log f_O}{E_i P_O} \right]}{\left[\frac{0.93S}{(g-1)} + \frac{S\gamma}{E_i} \right] (f_O)^{\frac{P}{P_O}} + \frac{P}{H} - \frac{S\gamma}{E_i}} dP = \frac{dK}{K} \qquad (31)$$

The above equation is of the form:

$$\frac{dy}{y} = \frac{[Ax + B]}{\left[D(f_0)^{-\frac{x}{P_O}} + Cx + E \right]} dx \qquad (31b)$$

where $x = P$, $y = K$, and

$$A = -\frac{\log f_O}{H P_O} \qquad (31c)$$

$$B = -\frac{S\gamma(\log f_O)}{E_i P_O} - \frac{1}{H} \qquad (31d)$$

$$C = \frac{1}{H} \qquad (31e)$$

$$D = \frac{0.93S}{(g-1)} + \frac{S\gamma}{E_i} \qquad (31f)$$

$$E = -\frac{S\gamma}{E_i} \qquad (31g)$$

We need to integrate both sides of equation (31). However, *the right side expression of equation (31), or (31b), is practically impossible to integrate if it were not for the fact that, after the multiplication of the denominator and the numerator of the equation (31b) by* $f_O^{\frac{x}{P_O}}$ *and with careful observation, it will be noted that the numerator of equation (31b) is the perfect negative differential of the denominator*. The reader can verify this by himself.

Equation (31b) can therefore be written as

$$\frac{dy}{y} = -\frac{du}{u} \qquad (32)$$

where

$$u = \left[D + CP(f_O)^{\frac{x}{P_O}} + E(f_O)^{\frac{x}{P_O}} \right] \qquad (33)$$

And integrating both sides of (32) we get,

log y = -log u + log C_1, or,

$$\log K = -\log\left[D + CP(f_O)P^{\frac{P}{P_O}} + E(f_o)^{\frac{P}{P_O}} \right] + \log C_1 \qquad (34)$$

Evaluating the integration constant C_1 at $K = K_O$ and $P = P_O$, we get,

$$\frac{K}{K_0} = \frac{D + CP_o(f_o) + E(f_o)}{D + CP(f_o)^{\frac{P}{P_0}} + E(f_o)^{\frac{P}{P_0}}} \qquad (35)$$

When $f_o = 1$, the above equation is reduced to equation (16) with $a = \frac{0.93SH}{(g-1)}$ as given by equation (13).

A plot of equation (35) with $f_o = 0.8$ and P_O = \$30/Bbl is shown in Figure 2.

As can be observed from this plot, the net effect is that, as oil fuel prices increases, the generation from the oil-based units is transferred to the more stable priced co-generators, as would be the case in equal incremental power dispatch. This effect is shown in Figure 2 by making the P vs. K curve more horizontal, thus making it less sensitive to further oil price variations and reducing hedging considerations.

V- CONCLUSIONS

Hedging of oil fuel prices in electric utilities is a very dynamic and continuously moving operation. It requires a detailed study of the parameters involved, which includes the production of KWhr sales per barrel of oil fuel (H), the unit price (S) of the KWhr sold (\$/KWhr), the fraction of the total load shared by the co-generators ($1-f$), the system transmission and distribution efficiency (E_i), the type of Energy Purchase Contract and its performance affecting an adjustment coefficient γ, adequate economic dispatch studies for fixing the relationship between oil price and power dispatch, the State Tax laws, and the levels of oil fuel price operations (P_O).

It is shown that incremental economic power dispatch can reduce the cost of hedging.

The classical curve for the elasticity of demand is a convenient tool to help in establishing the low and high limits for growth, which, in turn, are required in evaluating the cost of hedging.

A band between a high and a low oil price can be defined, where operations could be satisfactorily performed. It would be desirable if such band falls above the classical elasticity of demand curve.

The initial level of operation is a very important parameter. The lower the oil price, the higher is the oil price increase permitted in order to reach the established limits of sales reductions.

Hedging of oil prices should be avoided completely if the net revenues dependent on oil fuel prices are not affected negatively as determined by its elastic curve (equation 27).

The best and logical hedging process occurs with the substitution of more stable priced fuels in the generating plants.

Hedging values can be calculated by reading the percentage *sales drop* below the particular curve and the additional permitted percentage cushion drop, multiplying by K_O to obtain the KWhr drop, divide by H to obtain the number of oil barrels and multiply by the price of the barrel to obtain the full hedging cost.

VI- REFERENCES

[1] A. J. Wood and B. F. Wollenberg, Power Generation Operation and Control; John Wiley & Sons, Jan 1984.

[2] "Expected Cost Penalty Due to Deviation From Economic Dispatch for Interconnected Power Systems", IEEE Transactions on Power Systems, Vol. 10 No. 1 pp. 441-447, Feb. 1995.