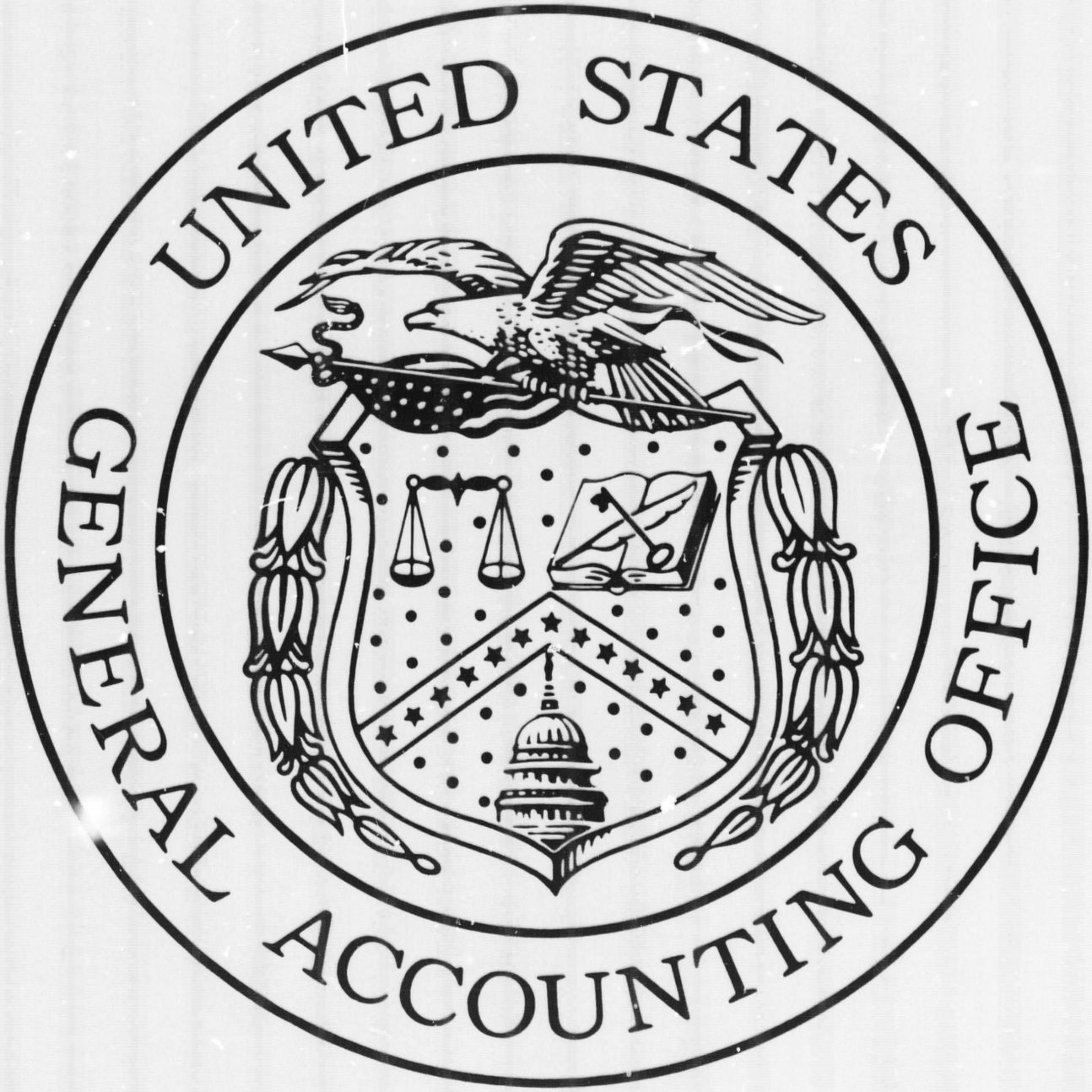
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Letter to Secretary, Department of the Interior; by J. Dexter Peach (for Monte Canfield, Jr., Director, Energy and Minerals Div.).

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

ENERGY AND MINERALS
DIVISION

B-114858

MAR 9 1977

The Honorable
The Secretary of the Interior

Dear Mr. Secretary:

Electrical energy is lost during transmission primarily because of resistance--the property of a conductor (line) which opposes the flow of current--in the transmission and distribution system. 1/ Achieving higher power factors 2/ results in lower resistance losses; thereby causing reduced energy losses.

Transmission and distribution system power factors normally range from 75 to 100 percent. Low power factors are generally improved by installing corrective devices, such as capacitors. With judicious use of capacitors, power factors of 90 percent and higher are common.

As part of our review of national efforts to promote and improve trarsmission systems, we examined the power factor requirements imposed by the Federal power-marketing agencies on their customers. Primary emphasis was given to the power factor practices at the Bonneville Power Administration (BPA), the Southwestern Power Administration (SPA), and four regions--Mid-Pacific, Upper and Lower Missouri, and Lower Colorado--of the Bureau of Reclamation.

1/ Electrical energy is lost during transmission and distribution because of certain laws of physics. Most losses are caused by resistance which transforms electricity to heat. Transmission involves moving power from generators to load centers at high voltages; distribution involves moving power for short distances to customers at low voltages.

2/ Power factor is a measurement of an electrical phenomenon which increases transmission line losses. Power factor is the ratio of energy available for useful work to apparent generated energy. It is expressed in percentages--the higher the percentage the lower the losses.

EMD-77-18

We believe the Federal power-marketing agencies can reduce energy losses on transmission and distribution lines, increase available line capacity 1/, and conserve energy by

--standardizing Federal power factor requirements and consistently enforcing them and

--developing Federal requirements which stipulate the method by which power factor correction is made to minimize energy losses.

Although electrical transmission and distribution systems are relatively efficient, total energy losses may approach 10 percent. Power factor improvement can reduce some losses. For example, a circuit experiencing 10 percent losses at a 70 percent power factor would reduce its losses to 5.44 percent if the power factor were improved to 95 percent.

High power factor is important in other respects. In distribution systems, the passage of current through the conductors causes a reduction in voltage along the way. If the reduction in voltage is too great there may be inadequate voltage for satisfactory operation of lamps, radios, television sets, and other types of electrical equipment. Motors are somewhat less sensitive to low voltage but tend to overheat if the voltage is low during heavy loads. Low power factor causes larger voltage drops.

Low power factor on transmission and distribution lines over great distances reduces the total available line capacity. Improved power factor through increased use of capacitors releases this capacity for transmission of useful power. As a result, the need for new power can be partially delayed by improving the power factor on existing facilities.

INCONSISTENT POWER FACTOR REQUIREMENTS AND INADEQUATE ENFORCEMENT BY FEDERAL POWER AGENCIES

Within the Department of Interior there are different

--power factor level requirements--90 and 95 percent;

--types of power factor measurement--power factor during monthly peak half hour, average peak power factor during peak months, monthly average power factor, and hourly power factor;

1/ Capacity is the maximum load for which a specific facility is rated. Low power factor reduces available capacity.

--methods of power factor measurement--continuous metering and random metering; and

--methods of enforcing customer power factor levels--penalty billing and verbal or written contact with customers.

Furthermore, Federal power customers do not consistently meet power factor requirements. Overall, 45 percent (124 of 273) of the fiscal year 1975 power factor readings and 41 percent (89 or 218) of the fiscal year 1976 readings we surveyed fell below the respective power agency requirements.

BPA

In fiscal year 1975 BPA sold power to 153 wholesale customers. Generally, all power factor levels were determined by meter readings. On the basis of meter readings, BPA determines its customers' usage (demand in kilowatt-hours) and their power factor for the billing period. Under the wholesale power rate schedules effective December 20, 1974, a purchaser of firm energy is subject to a penalty if their monthly average power factor is less than 95 percent. 1/

According to BPA's rate schedule, the adjustment imposed for not meeting the required power factor is a 1 percent increase either in the measured demand, measured energy, or minimum demand charge (depending on the particular rate involved) for each 1 percent by which the power factor is less than 95 percent (or power factor stated in the purchaser's contract).

BPA's penalty billing system appears effective. Of those Federal power agencies we surveyed, BPA appears to have the lowest power factor violation rate. A review of 22 of BPA's customers showed that in fiscal year 1975, 15 had their meters monitored. Only two of the monitored customers fell below their required power factor and received penalties. BPA's customers appear to be complying with the required power factor level; however, they must only meet an average level. As a result, during peak loads--the crucial period--customer's power factor level may be below the required level although their monthly average is sufficiently high.

1/ If the purchaser's previous contract contains an 85 percent provision, then the penalty level is 85 percent until July 1, 1977, when it changes to 90 percent. It remains at that level until July 1, 1978, at which time it becomes 95 percent.

SPA

SPA requires a 90 percent hourly power factor--the lowest level required by an Interior power agency--from each of its 65 customers. SPA has not recently studied the potential benefits and costs of levels higher than 90 percent. As stated in its rate schedule, "An hourly power factor shall be maintained at each point of delivery of not less than 90 percent * * *", SPA monitors 25 customers' power factor levels through monitoring at transformer locations. SPA has no penalty billing system. When customers fail to meet the power factor requirement, SPA contacts them by letter to request correction.

We discussed with an SPA official the advantages of the penalty billing system for SPA's customers who do not meet the required power factor. The official fully concurred with the need for a penalty billing system stating that SPA needs such a system to effectively enforce power factor requirements.

Bureau of Reclamation

All four Bureau regions we contacted require a 95 percent power factor from their customers. The Bureau arbitrarily set this level and has not studied the benefits and costs of it as compared to other levels. None of the Bureau regions practice penalty billing, written and verbal communication are used to encourage power factor correction. However, the type of measurement used, selection of customers to be monitored, and the frequency of monitoring vary among the Bureau regions.

The Bureau's Lower Missouri, Upper Missouri, and Lower Colorado regions determine their customers' power factor levels by attaching portable meters to their system either at random or during the historically established annual peak periods. Either continuous or peak and low-load power factor readings are used to determine if customers are meeting the required level. These readings are subject to availability of staff power and funds. The Lower Missouri region schedules customers to be monitored every 2 years, the Chief of System Engineering told us that shortages in staff power due to budget constraints caused monitoring to be discontinued during fiscal year 1975.

During fiscal year 1975, the Bureau's Lower Missouri Region monitored power factors for 9 of its 94 customers. Readings were made at 24 points. Eight customers and 21 monitoring points fell below the required power factor level.

During fiscal year 1975, the Bureau's Upper Missouri region monitored none of its 228 customers for power factor, however, 5 have been monitored in fiscal year 1976. Of the five, three had power factors less than the 95 percent level the Bureau now requires. The region monitored 121 customers for power factors from 1971 to 1974. For 30 of the 121 customers, the maximum measured power factor was below 90 percent.

The Bureau's Upper Colorado region has 23 contracts with agents for sale of Federal firm power that serve over 200 customers. Normally, the Bureau monitors only the agents of these contracts to determine if the required power factor is maintained. During fiscal year 1975, the region monitored only four agents and found one violation.

The Bureau's Mid-Pacific region monitors 25 of its 46 customers on a continuous basis. It records each customer's power factor every half hour. Customers must meet the 95 percent level during the half hour period that the monthly peak occurs. The Mid-Pacific region reports that about 40 percent (86 of 231) of its power factor readings for 9 months during fiscal year 1976 were below the 95 percent requirement. Only three customers successfully met the Bureau's requirement each of the 9 months monitored. Furthermore, two customers never met the required level during the 9-month period. The average power factor recorded by customers failing to meet monthly requirements was 89.9 percent. In fiscal year 1975, 246 meter readings were made, 113 (46 percent) of these were below the required 95 percent power factor level. The Assistant Regional Director has stated that the Bureau needs a penalty billing system to effectively enforce customer power factor requirements.

CURRENT POWER FACTOR REQUIREMENTS MAY NOT MINIMIZE ENERGY LOSSES

Since the level of energy loss reduction from power factor improvements is dependent upon how close to the load the correction is made (for example, placement of capacitors), the location of power factor correction devices becomes important. Therefore, even when Federal customers meet power factor requirements, transmission and distribution losses may not be minimized and later energy savings realized because the Federal power agencies have no requirement regarding the method by which the level is achieved.

Power factor correction can be made through various applications of continuously operating capacitors, switched capacitors, or both at various locations on the transmission

and distribution system. Most utilities, however, attempt to place capacitors along the distribution circuits. We contacted 24 utility companies of which all but 1 made it a standard practice to place capacitors along distribution circuits where practical.

In one study, the Southern California Edison Company applied capacitor application theories to underground circuits. Its results have shown it is advantageous to place fixed capacitors along the circuit rather than at the substation.

We studied the potential benefits of improved power factor on the distribution system operated by a municipality purchasing its power from the Bureau's Mid-Pacific region. Three circuits were studied--an underground industrial circuit; a partially underground combination circuit serving residential, industrial, and commercial buildings; and an overhead residential circuit.

The residential circuit's power factor was already high and significant improvement could not be expected or economically justified. Considerable losses could be saved through installing additional capacitors to the underground industrial circuit, but the capacitors could not be economically justified by the energy saving alone. The installation costs of special capacitors for the underground circuit raised the total cost too high to be justified.

The remaining two circuits had power factor levels between 85 to 90 percent. If the existing capacitors on the combination circuit did not have capacitors then the power factor would have been about 75 percent. The other industrial circuit had no capacitors.

Our study revealed that improving the power factor--through application of additional capacitors--from an average 87 percent to 97 percent (since unity power factor is not practical, we assumed improvement to the 97 percent level) in industrial and combination circuit branches would reduce distribution losses by 22.4 percent. 1/

1/ We used the formula $\Delta P_L = |I|^2 \left(\sin^2\theta - \frac{\cos^2\theta}{\cos^2\theta'} \sin^2\theta'\right)$

where ΔP_L = reduction of distribution losses
I = current in line
θ = the phase angle for a power factor of 87%
θ' = the phase angle for a power factor of 97%

The energy saving resulting from the addition of capacitors to the combination circuit was sufficient to pay the cost of the capacitors needed to increase the power factor level to 97 percent. Capacitor arrangement along the distribution lines would also improve the conditions on the subtransmission lines feeding the substation and produce savings. However, sufficient data was not available to fully examine this benefit. Our analysis showed an annual savings of 33,988 kilowatt-hours for this circuit alone. When combined with the demand savings, and using the costs applicable to the municipality's system, the benefit to cost ratio is 1.44:1 for an unswitched bank of capacitors. If switched capacitors are used, the benefit to cost ratio is 1.30:1. In addition, the energy would be conserved. None of the savings calculated in this case would be realized if the capacitors were placed in the substation. Since these lines are not yet heavily loaded, potential to reduce energy losses and increase usable line capacity is not as great as for lines that are heavily loaded.

In the above case, capacitor application can be justified by the energy saving in the municipality's distribution circuit alone. It is evident that locating power factor correction devices on the lines is preferable to power substations. Our analysis showed cost beneficial energy savings in one distribution circuit of a Federal power customer, but there are over 600 Federal power customers in the United States. While opportunity for energy saving may not exist in all these customers' systems, we believe potential saving may be significant enough to justify study and appropriate action to insure maximum energy conservation.

Officials of the Bureau's Mid-Pacific region agreed that optimum energy saving is dependent upon locating capacitors close to the load on the distribution circuits. Power factor improvement requires technical study for each individual circuit, requiring expertise and resources many municipal customers do not have. While there is no provision for the Federal Government to assist such customers in designing their capacitor applications, the Assistant Regional Director noted that the Bureau's Irrigation Management Service--providing service to water customers that includes technical consulting--has set a precedent for technical assistance to Federal customers.

CONCLUSIONS AND RECOMMENDATIONS

A significant number of Department of the Interior power-marketing agency's customers have failed to meet their respective power factor level requirements. As a result, opportunities to minimize transmission and distribution energy losses, increase available capacity, and better conserve energy have not been fully realized.

Furthermore, power factor requirements and monitoring and enforcement practices among power-marketing agencies are inconsistent and appear to be ineffective. Verbal and written requests by power-marketing agencies have failed to achieve corrective action. Only BPA, which practices penalty billing against power factor violators, appears successful at encouraging customer compliance.

Inadequate monitoring of customer power factor levels has allowed power factor violations to occur. Only the Bureau's Mid-Pacific region monitors power factor continuously. Most other power-marketing agencies randomly monitor power factor. As a result, only part of an agency's total customers are monitored each year. This low level of monitoring indicates that power agencies give power factor correction a low priority.

Finally, power factor requirements that do exist do not encourage correction at the most appropriate location. Since Federal power factor requirements do not stipulate by what method power factor correction will be made, corrections may not occur at points closest to the load. As a result, transmission and distribution losses may not be minimized. Our benefit-cost study of a Bureau power customer indicates a better than 1:1 ratio for improving power factor to 97 percent on one circuit. This correction would result in savings of 33,988 kilowatt-hours per year when capacitors are applied to the circuit rather than at the substation.

We recommend that the Secretary of the Department of the Interior require the power-marketing agencies to:

--Study existing Federal power factor requirements, as well as higher levels, to determine the level at which energy savings and released capacity will be maximized. Unless system operations unique to a specific agency or region indicate otherwise, the Department should standardize its power factor requirements for all agencies. All elements of a power factor requirement, such as type of measurement, method of monitoring and enforcement, and how often measurements are made, should be consistent throughout the power-marketing agencies.

--Establish standard monitoring procedures that would insure contractual compliance by Federal customers where appropriate.

--Enforce customer power factor levels through a penalty billing system. Penalty levels established should be sufficient to insure that customers correct low power factors. Further, the customers should be made aware of the benefits they can achieve by correcting low power factor at locations along their system that will minimize distribution losses.

We discussed this report with officials of the Bureau of Reclamation and the Bonneville Power Administration and they generally agreed with our conclusions and recommendations.

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As you know section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the House Committee on Government Operations and the Senate Committee on Governmental Affairs not later than 60 days after the date of the report and to the House and Senate Committees on Appropriations with the agency's first request for appropriation made more than 60 days after the date of the report.

We are sending copies of this report to the Director, Office Management and Budget; appropriate congressional committees; your Commissioner of Reclamation; the administrators of the Bonneville and Southwest Power Administrations; and the Regional Directors of the Bureau's Lower Colorado, Lower Missouri, Upper Missouri, and Mid-Pacific regions.

We appreciate the cooperation received during our review and would like to be informed of any action taken on our recommendations. We would be glad to discuss this report with you or your staff.

Sincerely yours,

Monte Canfield, Jr.
Director