Wheeling of wholesale electric power and energy from a seller to a buyer through the transmission system of a third party has taken place on a commercial basis for many years. This article demonstrates how improvements in regional economic efficiency are achieved by interconnection and by wheeling. It discusses considerations entering into the setting of wheeling fees and their impacts on the amount of economy energy transferred and on economic efficiency. It is concluded that there is a dearth of hard information on these impacts. Interconnection and wheeling should be more thoroughly explored, through available simulation models, before existing regulatory powers are extended to regulate wheeling.

Il y a déjà plusieurs années que le transit commercial en gros de la puissance électrique et de l'énergie est effectué entre le vendeur et l'acheteur par l'intermédiaire d'un tiers. Cet article démontre comment le bon fonctionnement de l'économie régionale profite de l'interconnexion et du transit. On y examine la façon dont les tarifs de transit sont fixés et l'impact qu'ils ont sur la quantité d'énergie transportée et sur l'efficacité économique. Il est conclu qu'on manque grandement d'information solide au sujet de cet impact. Les questions reliées à ce transit méritent donc plus de recherches, à l'aide de modèles disponibles, avant que les pouvoirs régulateurs actuels ne soient appliqués au transit.

Economic Efficiency and Wheeling: A Framework for Analysis

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Much of the recent public discussion of the electricity supply industry has focused on the question of economic efficiency and has been equally critical of publicly- and privately-owned undertakings. Underlying the discussion has been a suspicion that the managements of large utilities have not achieved optimal levels of economic efficiency. The debate over this issue, in a field which previously had been the preserve of engineers and industry specialists, has involved specialists in economics, law and public affairs. As a result, the examination of the industry has extended into areas rarely before exposed to public scrutiny.

In the United States, where 75% of electricity is generated by investor-owned utilities (IOUs), one area undergoing close examination is the potential for improved use of the transmission network, which they largely own. It is argued that economic efficiency will be enhanced if third parties are given access to the network and allowed to transmit energy between buyers and sellers without restriction. The buyers and sellers may be utilities, cogenerators, large industrial plants, cooperatives and municipal utilities, with and without owned generating capacity. Many of these want to transport energy over existing transmission networks (Bushnell, 1987).

While some argue in favour of making it com-

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pulsory for owners of transmission lines to allow wheeling, it is probably the case that the profit motive has already brought about most of the benefits of interconnection that are justified economically and technically, including wheeling. That is, compulsory wheeling would have only a limited net benefit, if any.

This paper proposes a framework within which the impact of wheeling on economic efficiency may be analyzed and suggests some conclusions that can channel the ongoing debate more productively. In particular, it is argued that, before legislative and regulatory changes are made, additional modelling analysis should be used to determine the gains that might be made.

1. Interconnection and Economic Efficiency

Before examining the implications of wheeling, it would be desirable to review the way in which utilities have achieved present levels of fuel efficiency through technology that has evolved over the past hundred years.

1.1 Economic Dispatch

The principle of economic dispatch is well understood — an operating utility will generate energy first from those of its machines with lowest marginal production cost and, as demand increases, will dispatch load from progressively more expensive machines, so that demand is always met. The marginal cost of generating the next kilowatt-hour (kWh) of energy is mostly the cost of fuel, with some incremental costs of maintenance and supplies; this marginal cost is called "system lambda" in the industry.

When a storage reservoir permits hydraulic energy to be stored, dispatchers will postpone use of the stored water until it has maximum value in supplying system demand or export sales. Hydraulic energy from rivers without storage is generated "as the stream flows," and is always used before generating thermal energy. These special cases are consistent with economic dispatch, which minimizes the cost of supplying system energy and export sales.

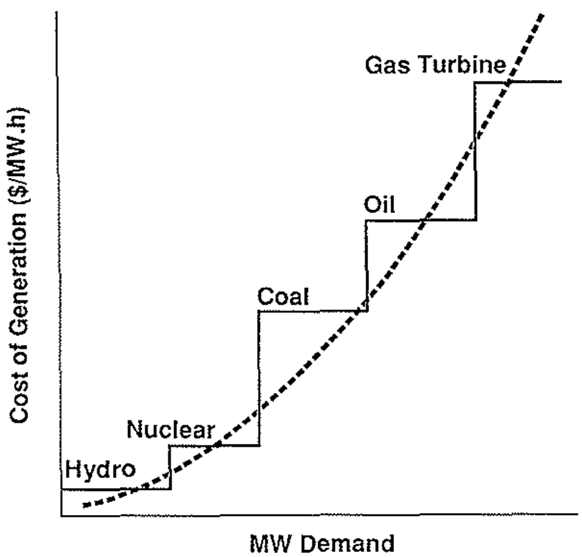

Figure 1: Typical Fuel Cost Relationships

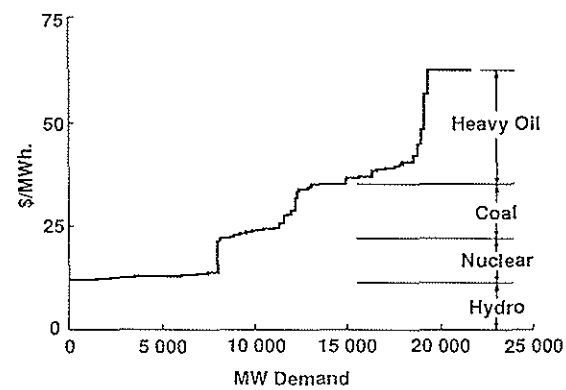

Figure 2: Real Incremental Cost Curve

The exceptions to this general rule occur when thermal units supply process steam or heating requirements and "must run," or when a nuclear unit has a physical restraint on how fast it can pick up or drop load.

A generalized marginal cost curve of a power system is shown in Figure 1. At any value of demand (MW), the cost of generating one more MWh is measured on the vertical axis. Figure 2 shows the curve plotted for an actual system, based on machine efficiencies (BTUs/kWh) and fuel costs ($/BTU). These curves are typical of power systems operating in isolation, i.e., without interconnections with other power systems. Today, if one finds an isolated system it is because interconnection is impossible or uneconomic.

1.2 Interconnected operation

Historically, most power systems have become interconnected with neighbouring utilities with the primary objective of assuring a reserve supply for emergency situations. The interconnections permit exchange of power and energy at other times to reduce the cost of meeting demand. For example, a contract for the purchase of firm power may enable one utility to postpone the installation of new capacity, hence reducing its capital charges. At the same time, the seller will be able to spread its capital charges over a broader base. On the other hand, a contract for the purchase of economy energy, which is usually interruptible (i.e., the exchange may be terminated at the seller's option), enables the buyer to save on fuel costs. Usually firm contracts are for a longish time period (years), while economy exchanges may be made for as little as one hour.

Two contiguous power systems will each have a unique incremental cost curve depending on the parameters of their machines and the cost of their fuels. In supplying native load (i.e., the demand of customers in its own concession area), each system may find that it is operating at a different marginal cost. If a transmission line joins the two systems, it will be economically advantageous for the system with the lower marginal cost (lambda) to sell energy to the higher-cost system. The transfer of energy will result in a lower joint (regional) fuel cost, because the saving in the high cost system will be greater than the increase in fuel cost for the low cost system. Thus, there will be an improvement in economic efficiency because of the transfer. (While this measure of economic efficiency has been expressed approximately in terms of fuel cost, it can be extended to include all incremental costs.)

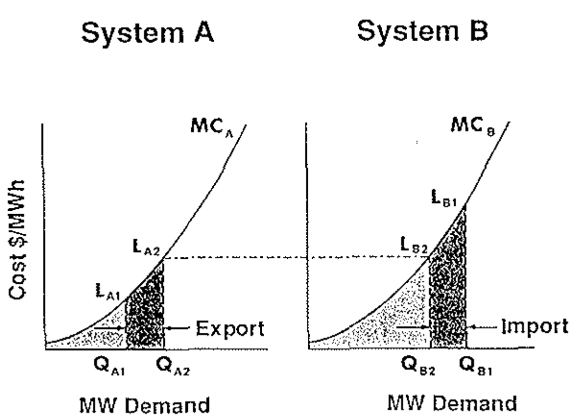

Figure 3: Marginal Cost Curves for Two Power Systems

Figure 3, in which the stepped curves of Figures 1 and 2 have been replaced by smooth curves, illustrates the exchange. It shows the unique marginal cost curves of two power systems, designated System A and System B. System A has a native load Q_{A1}, a cost of generation represented by the shaded area under the curve MC_A, limited by the vertical axis and by Q_{A1}-L_{A1}, and its marginal cost is L_{A1}. System B has a native load Q_{B1}, a cost of generation represented by the shaded area under the curve MC_B, limited by the vertical axis and line Q_{B1}-L_{B1}, and its marginal, or incremental, cost is L_{B1}. Since $L_{A1}<L_{B1}$, it is logical that net benefits can be realized through the sale of energy by System A to System B, and that there is potential for more benefits until the marginal costs of generation of the two systems are equal. This is shown, where System A generates Q_{A2} and exports a quantity (Q_{A2}-Q_{A1}) to System B, whose generation is now reduced to Q_{B2} by the importation of (Q_{B1}-Q_{B2}). The cost of the generation of System A's export is represented by the area $Q_{A1}L_{A1}L_{A2}Q_{A2}$, which is System A's increased or "incurred" cost. System B's generation is reduced in cost by the area $Q_{B1}L_{B1}L_{B2}Q_{B2}$; this is the "avoided" cost due to the import. The saving from the transaction is a net benefit (= avoided cost - incurred cost) and System A and System B must decide how to divide the benefit.

In any hour, the two utilities will exchange energy until their marginal costs are equal, or until the capacity of the transmission line interconnecting them ("transfer capacity") is reached. It must be remembered, however, that there is a cost involved in negotiating and carrying out a transfer transaction; when the net benefit, as defined above, is less than that cost, the systems have no incentive to consummate the transaction. The transactions cost defines a "Dead Band," which will prevent the achievement of the last increment of electricity trade.

1.3 Multiple Interconnections

When several systems are interconnected into a network, each system may have a choice of trading partners. It can be shown that the most rapid improvement in efficiency will be effected when each transaction matches the seller with the lowest marginal (incremental) cost and the buyer with the highest marginal (decremental) cost. If each system is buying and selling by way of bilateral contracts, the achievement of significant improvements in efficiency requires a widespread knowledge of the operating costs of all the interconnected systems. One method for making this information available to all the participating systems is called the **Brokerage** system: at the beginning of each trading period, each participant declares the price at which he will enter into a "purchase" agreement and the volume needed at that price; he also states the price at which he will enter into a "sell" agreement, and the quantity. Ideally, the price would be his system's marginal cost in each case, although actual cases have shown that specific considerations, or even cheating, may cause posted prices to depart from the optimal levels. With appropriate allowance for transmission losses and other valid considerations, bilateral contracts made at the posted prices and volumes, high buyer to low seller, will allow the gain in efficiency to approach the optimum. That is, all possible trades with net benefits greater than transactions costs will take place.

Without a schedule of buy/sell prices available to all participating utilities, the improvement in efficiency will not likely approach the optimum. In two well known experiments, the Florida Brokerage (Cohen, 1982) and the Southwest Experiment (Acton and Besen, 1985), the information on pricing was provided through computerized information systems and the results showed a substantial improvement in regional efficiency.

1.4 Pooling

Pooling is one response of the IOUs to the challenge to approach the limit of economic efficiency in electricity supply. In the US, many forms of pools have evolved (Federal Energy Regulatory Commission, 1981), from very tightly organized corporate entities, like NEPOOL in New England, to loose arrangements for mutual support at times of emergency. If the pool incorporates the joint dispatch of generating equipment (i.e., if all participating members allow their generators to be dispatched by a central control centre, in accordance with the principles of economic dispatch), it will likely go as far as is possible in the pursuit of short-term fuel efficiency, considering the hard costs that are incorporated in the usual criteria for economic dispatch. Pooling agreements take into consideration many factors in addition to fuel and maintenance costs and transmission losses — transmission limitations, regulations that limit thermal generation when atmospheric pollution exceeds statutory limits, downstream riparian rights in times of low stream flows, etc. Such constraints limit the extent of trading, but within them, joint dispatch achieves the optimal level of economic efficiency. This result can be used in modelling work as a reference with which to compare other network arrangements and inter-utility buy/sell contracts.

1.5 Limitations of Interconnections

A network is made up of a number of interconnected systems, which may include two party systems, multiple interconnections and pools. All forms of interconnected networks can exchange power and energy up to real limits set by the physical parameters of the components of the network. The limits vary through time; e.g., the current-carrying capacity of conductors of a transmission line is higher in cold weather than on a hot summer day. These are engineering, not economic, limitations in the short term. Taken all together, the physical limits form the basis of decision-making at the operating level. Each limiting factor in itself sets an achievable limit of economic efficiency and, taken together, may constrain it to a disappointing practical result.

In the longer term the limitations may be reduced or removed at a real cost. The engineering, financial and economic criteria that govern such system expansion are well known. However, in recent years the conventional means of reducing the physical constraints on power systems have been closed out one by one. Resistance due to the tendency of those affected to invoke the "NIMBY" principle,[1] low rates of load growth, respect for the environment, the risk element in future financial rates of return and other factors have all contributed to the stagnation of expansion.

In the past, utilities have determined the reliability of electricity supply of their customers. It is not clear that it will continue to be determined in the same way. As demand increases, the aggregate of the engineering limitations will test the level of reliability that a utility's customers want. The flexibility of the utility's decision making in solving supply problems is circumscribed by how much customers are prepared to pay in both direct and social costs. The role of pressure groups, the media and parties directly involved are often in conflict; the utility may at some time be unable to get a clear reading on what to do and how to do it.

1.6 Interconnection and Fuel Efficiency: Summary

While most transmission lines that interconnect power systems have been built with the primary objective of improving reliability, they also permit the exchange of energy for other reasons, which has improved operating efficiency in both the short and the long term. In general, the more widespread the interconnected network, the greater are the opportunities to improve economic efficiency. On the other hand, technical problems become more complex as the network expands and this may put a ceiling on achievable improvements in efficiency.

Weak transmission links prevent the optimal transfer of energy. New lines, to increase inter- and intra-system transfer capacity, will overcome this limitation on the improvement of efficiency, provided that new technical constraints are not introduced as a result of the expansion of the network.

Wheeling is analogous to new transmission capacity, for it makes use of existing lines to transfer energy between non-contiguous systems which have no direct interconnections. Wheeling cannot, however, improve economic efficiency beyond the level achievable in a network that operates, with the same physical elements, under an agreement which pools generation and transmission under joint dispatch.

2. Wheeling and Economic Efficiency

2.1 What is Wheeling?

Referring to Figure 3, suppose that systems A and B are not contiguous, but rather are separated by the concession area of a third system, C. A and B can enjoy the benefits of exchanges of economy energy only if they can arrange for the transport of energy through C's transmission system. System C has three options:

- not to transfer the economy energy;
- to buy from the system with low marginal cost, for its own use, and sell to the system with the high cost from its own capacity thereby made available; or
- to allow the energy to pass through its system for a consideration, without taking ownership of it.

Wheeling is the third option, where a third party provides a transmission service to the buyer and the seller for a fee. The "third party" may be more than one system interposing between the buyer and seller.

The wheeler may affect economic dispatch of

1/ NIMBY = Not in my backyard.

generation in a network in a number of ways, including:
(1) he may limit the exchange of energy below the optimal level; and
(2) by charging a fee, he in effect increases the "Dead Band."

Thus the wheeler will reduce the amount of energy transferred and can limit the improvement in economic efficiency below that which might be achieved with joint dispatch of the three-system network. He will also affect the distribution of the benefits arising out of the transaction.

In the US, all contracts for wheeling services are approved by the Federal Energy Regulatory Commission (FERC). In 1985 there were 1500 contracts on file. Despite this evidence of negotiated cooperation, there was sufficient doubt that efficiency objectives were being achieved to cause FERC to issue a Notice of Inquiry (NOI) (FERC, 1985) in order to look into the movement of economy energy and the evidence on wheeling. The question of access to transmission networks by generating companies which are not regulated utilities, and by customers who felt that they could buy energy more cheaply from sources other than their traditional supplier, was a substantial concern of the submissions in the Inquiry. It is probably fair to say that the NOI was precipitated by controversy over financial issues, not over economic efficiency, but, given its regulatory responsibilities, FERC had to follow up with an examination of the case for efficiency. Elements of the same debate are arising in Canada, although the fact that concession areas of Canadian utilities are province-wide eliminates one of the reasons for the importance of access that applies in the fragmented power supply map of the US.

In both countries the fact that electric utility companies have monopolies in their concession areas helps to motivate the debate over wheeling, which is viewed as an avenue through which a new element of competition can be introduced. It is perhaps useful to review briefly the evolution of this monopoly power.

In the early days of the electricity supply industry, before there was a regulatory mechanism, any entrepreneur could undertake to supply his product, in free competition, subject only to the authorization of the "city fathers." In Chicago, in the period 1882-1905, it reached the point that 29 companies had been given franchises, of which three were city-wide. The story (Hyman, 1983) is a fascinating one. The significant point here is that the supply companies finally requested that they be given a monopoly of supply in specific franchise areas: in return they would accept a responsibility for reliability and tariff regulation by a public regulator. The compact reached at that time set the pattern in the United States for many years, until quite recently, when the industry came under scrutiny because of concerns that economic objectives of the individual monopolists were not coincident with national economic goals. The NOI mentioned above was part of the expression of that concern, specifically in the sectors of exchanges of economy energy, and wheeling and access for wheeling. The utilities on the other hand have felt that the agreement between industry and governments was being broken by over-regulation on the part of regulators more concerned with short-term consumers' approval than the long-term reliability of electricity supply. In particular, IOUs have felt that their large investment in transmission entitled them to decide who should use it and at what price.

The Canadian scene developed similarly in the initial years, but very early, provinces began to think in terms of provincial monopolies. Today, only Alberta and Prince Edward Island have provincial supply by IOUs. Each province has a unique regulatory mechanism. Because the land area of most provinces is so large, and in most cases indigenous resources were large in relation to demand, there was little motivation to wheel or exchange energy between provinces. In recent years, with the realization that the resource base was not unlimited, and with the development of EHV transmission, provinces have come to realize that there are economic opportunities for trading outside the provincial boundaries. Wheeling through other provincial facilities to third parties in Canada and the US is now an issue in a number of regions. The more prominent cases in which wheeling either goes on, as in the Maritime Provinces, or is being considered are:

NB Power — NS Power — Maritime Electric (PEI)
Quebec — Maritime Electric
NS — NB — New England
Newfoundland & Labrador — Quebec — New England
Quebec — Ontario — US Midwest
Manitoba — Saskatchewan — Alberta
Alberta — BC — US Northwest

In addition, most Canadian exporters of electricity need to enter into wheeling contracts with US IOUs to sell in the fragmented export market south of the border.

Finally, in both countries the wheeling issue is important in relation to its potential role in allowing small independent power producers (IPPs) to market their services by using the transmission lines of the large utilities. The special aspects of wheeling specific to IPPs are not dealt with in this paper.[2]

The remaining discussion assumes that territorial monopolies continue to exist, but that the owners of the transmission systems will not refuse to wheel if there is a benefit to be shared from an exchange of economy energy.

Thus it is apparent that wheeling is currently an important subject and that the interplay between locational advantage, private property rights, historical contracts and provincial/state jurisdictions and aspirations is in flux. Since it is argued that changes are needed to improve economic efficiency, as well as to meet financial objectives, a more precise determination of benefits which might be made by wheeling is necessary. Before departing from the practices in power supply which have evolved over many years, to pursue a legislative path to enforce access or to regulate fees, it would be prudent to assess the incremental improvement that might result from a regulatory solution as contrasted with the voluntary solutions that have brought us to the present position. Perhaps incentives under the present practice of voluntary negotiations will achieve a pragmatically adequate level. While this paper does not attempt to survey whatever quantitative evidence exists, the delineation of relevant issues regarding fee setting set out below can be helpful in pursuing the matter further.

2.2 Market Fee Structures

As described above, benefits from trade arise out of the saving in expenditure on fuel and other incremental costs. In a bilateral transaction, without wheeling, the difference between the avoided cost of the buyer and the incurred cost of the seller comprises the benefit, whether the parties are simply interconnected or are part of a network of many utilities. The division of benefits between buyer and seller is a matter of negotiation, which may be resolved in a number of ways depending on technical or financial circumstances. A frequently used approach is the "split savings" formula, by which each party receives half the net benefits. For purposes of the following discussion, this formula is considered the normal method of sharing the benefits arising out of the bilateral transfer of economy energy.

A pooling agreement may prescribe other formulae for the calculation of benefits and their division among pool members. The underlying principle remains the same, however: that the low cost utility receives payments originating with the high cost utility.

It is understood that the managers of intersystem trading in participating utilities have among their assigned objectives the maximization of net revenue from buying and selling energy and that they are rewarded in ways that can incite them to pursue this objective with enthusiasm.

Introducing wheeling into the process adds another level of transaction fee. FERC has on file thousands of contracts for the provision of wheeling services. Each of these is individually

2/ The analysis also focuses more on exchanges of economy energy than on the transfer of large blocks of firm power and is less applicable to the Canadian scene than to that of the US. The basic ideas are, however, similar for both countries.

negotiated. Since terms are specific to each agreement, all of them cannot be described here. The majority fall into three classes:

(1) those in which the wheeler's fee is based on the dollar value of the total benefits of the transaction;

(2) those in which the fee is determined on a unit basis — dollars for each kilowatt hour and/or kilowatt transferred; and

(3) those in which the fee is based on embedded cost (book value, or sometimes replacement cost), with add-ons for losses and incremental operating costs.

Here it is assumed that the buyer pays the wheeling fee. Note that this is a limiting assumption. The wheeler is asking to share in the benefits of the trading transaction and, if his fee reduces the buyer's benefit to zero, it is unlikely that a transaction will be consummated. It can be argued, of course, that the seller also has an interest and would be inclined to share in the wheeling fee, rather than see the transaction default. This alternative will not be pursued.

2.3 *Considerations in Setting Fees*

The following are the major considerations, applied separately or in some combination, that will enter into a wheeler's evaluation of a proposal to wheel and the setting of a fee.

EMBEDDED COSTS

Embedded costs relate to the book value of the capital installation required to transmit power. At any time, this value will reflect the initial capital cost, less depreciation, plus any expansion to the facility since its initial construction. The wheeler may assess a proportion of its annual embedded capital cost as a wheeling fee (for example, an amount proportionate to the ratio of the power or energy wheeled to the capacity of the line). Operating costs may be added to the embedded costs in calculating the annual fee.

REPLACEMENT COST

Rather than embedded cost, consideration may be given to replacement cost, particularly if an existing transmission plant has insufficient capacity to carry the power/energy that can be economically exchanged between a buyer and seller and there is no alternative to upgrading the facility used or building new facilities. Again, it is likely that some proportion of this new cost would be assessed rather than the full cost.

MARGINAL COST

With given facilities, the marginal or incremental cost of providing transmission services to a buyer and seller includes the cost of transmission losses, additional administrative expenses, loss of life of equipment (occasionally) and, sometimes, the loss of profit because the wheeler has to forego other transactions in order to honour his wheeling contract.

REVENUE AND/OR SAVINGS FOREGONE

Because the wheeler has a locational advantage, and on the assumption that he may choose whether or not he wishes to wheel energy for others, he may estimate the revenue/profit he might make by buying from the low lambda system for his own use and selling to the high cost system from the generators freed up by his advantageous purchase. Using this target revenue/profit as the base for the rate charged is described by some utilities as "being made whole" by the wheeling transaction fee.

MONOPOLY PROFIT

The preceding option suggests that opportunity cost may determine the fee. Carrying the argument one step further, locational advantage may be used to extract monopoly profits. That is, the wheeler, having some knowledge of the joint savings of each transaction, may demand a fee greater than might be arrived at through the other options.

3. Practical Solutions to Fee Setting

In this section we consider some basic fee structures. Three points should be noted in advance.

(1) Firm power contracts are a special case; the conclusions here are more particularly applicable to interruptible economy energy.

(2) Most of the fee structures actually used can

be related to one or other of those examined below.
(3) In actual cases operating and engineering constraints not considered here may affect real fee structures.

3.1 Postage Stamp Rate

The wheeler charges a unit fee for each kW or kWh wheeled. The rate is easy to understand and to apply. Such a fee structure effectively decreases the difference between the marginal costs of the buyer and seller. Therefore, in models of networks used to examine wheeling, this rate suppresses some low value transactions and reduces the amount of energy transferred.

By appropriate assumptions of power and energy transmitted, the postage stamp rate can be related to embedded or replacement cost and operating expenses. It is difficult to relate a major item of cost, transmission losses, to a unit rate. The postage stamp rate does not relate directly to benefits or to opportunity cost once the contract has been agreed upon.

3.2 Percentage of Benefits

In this case, the wheeler charges an agreed percentage of the benefits derived by the sale of energy from the low cost utility to the high cost utility. The rate is easy to understand and apply. It does not relate to the wheeler's embedded cost, opportunity cost or marginal cost. To obtain net benefits, transmission losses may be estimated to adjust the gross differential marginal cost of the buyer and seller.

The fee redistributes benefits, but it is unlikely to suppress exchanges or affect efficiency if the percentage charged for the wheeling service is below 50% of the net benefits. If it is more than 50% the seller would have to share the wheeling charge and his behaviour may be affected. A fee of 100% or above would of course suppress all transactions.

3.3 Percentage of Avoided Cost

The wheeler charges a percentage of the avoided cost of the buyer, i.e., the savings by the purchaser in fuel cost and operating expenses. This option is more difficult to justify.

The fee does not relate specifically to the costs incurred by the wheeler, to opportunity cost, or to benefits. It singles out the buyer's fuel savings without accounting for the amount he pays for the purchased power. Such a fee suppresses transactions where the differential marginal cost is small, and therefore prevents optimal efficiency from being achieved. The higher the percentage, the more transactions are suppressed.

The fee is not difficult to understand, but it makes it almost impossible to estimate in advance the effect of wheeling on energy exchanges, benefits and efficiency. Intuitively, it appears this fee structure would have more negative effects than the postage stamp rate.

3.4 Leasing or Auctioning of Capacity for a Lump-Sum Fee

The wheeler may have surplus transmission capacity and may wish to take an initiative to maximize its return on investment by contracting its use out to other parties. In the fragmented networks in the US, auctioning has been tried when the excess capacity is of interest to a number of undertakings. Where the capacity is desirable to only a single undertaking, auctioning is not relevant and a negotiated lease is the practical alternative. Since the cost of the surplus capacity is a sunk cost, the fee should lie between the incremental cost of the wheeler and the benefits of the energy exchange made possible by access to the capacity. There is no difficulty in relating this option to the realities of a free enterprise economy.

A lump sum fee having been agreed upon, the trading partners would have an incentive to exchange a maximum amount of energy. This outcome would be modified if a formula for the cost of transmission losses were to be included in the lease pricing. The trading partners may wish to calculate the size of the transfer that would minimize the unit cost of energy. If the lump sum fee is large, the potential trading partners may decide that the wheeler is taking too large a share of the benefits and reject the service. In this case, efficiency improvements may still occur through bilateral exchanges between the wheeler and each of the two trading partners, but the result would probably be less favourable than if wheeling took place.

3.5 Revenue/Benefits Foregone

A wheeler located between two utilities that wish to exchange economy energy may consider the option of buying from the low-cost utility and selling to the high-cost neighbour. If he chooses to wheel, he foregoes the trading revenue and may wish to be "made whole" by the wheeling fee. The fee in this case may be based either on revenue or other benefits that could accrue to the wheeler through the buy-resell transaction.

This fee bears no defined relation to embedded or replacement cost, to benefits accruing to the buyer or seller or to the wheeler's incremental cost. As with the case of the lump-sum lease, the fee will suppress low value transactions.

3.6 Dynamic Selection

A wheeler who wishes to maximize profit may change the fee structure to suit system circumstances — in any time period he may assess fees on any of the above bases. While this requires great operational agility, and trading partners that are anxious for the service, it may be a practical strategy in certain situations.

The wheeler may also be in a network in which he faces a choice of several wheeling or buy/sell opportunities simultaneously. His behaviour will be a function of the profitability of the several alternatives and his capacity to implement them. A mixed strategy may emerge in which the fees relate to all or none of the above considerations.

3.7 Impacts of Fee Structures

It is immediately evident from the characteristics of approaches to fee setting in the above list that the nature of the fee will affect the contribution of wheeling to economic efficiency. For example, a postage stamp fee, that decreases the differential between the incremental cost of a potential seller and the decremental cost of a potential buyer by a constant amount on each kWh, will reduce the net benefit to be shared on each unit traded. The size of the per-unit fee affects the point at which the net benefit reaches zero and the expansion of trade ceases. Contrast this with the lump-sum fee that acts as a rental charge for the use of part of a line's capacity for a stated period. When a buyer and seller decide that energy transfers will justify paying the lump-sum fee, it will be to their advantage to use the service to the maximum and that maximum will be greater, other things given, than in the case of the postage stamp fee.

Thus the behaviour of the wheeler in structuring and setting a fee influences the extent to which efficiency gains are achieved through trade. In some way, the fee of the wheeler will always reduce the amount of energy transferred, suppressing at least the low profit transactions. The amount by which efficiency gains will fall short of the practical limit will be dependent on the magnitude of the wheeling fee — other things equal, the higher the fee, the greater the shortfall.

It is clear, of course, that, because the resources available from the wheeling utility will generally have alternative uses, a wheeler's fee is itself justified in terms of economic efficiency. The social efficiency objective is to have the wheeler charge a fee that covers the real cost of resources used in wheeling, and, with that constraint satisfied, does not further limit transfers between utilities that can benefit from them. If the wheeler is a regulated undertaking, it will presumably be the regulator's objective to establish such prices for wheeling — prices that allow wheelers to earn a competitive rate of return on the capital used in providing the service.

4. Is Wheeling Fair?

Wheeling, as it is brought about by negotiation between a buyer, a seller and the wheeler, is the epitome of free enterprise. Rights of property are observed, there is a profit to be shared between the three parties and the three parties reach agreement without intervention by society.

Sometimes the profitability is not sufficient to justify transactions and therefore the last ounce of fuel saving is not realized. On the other hand, electric power utilities have always recognized that reliability of supply and discharging the contract for service to their customers depends on cooperation. Wheeling in times of emergency frequently occurs, but may not be patterned on normal terms of negotiated contracts.

There is an underlying suspicion outside the industry that the utilities themselves will not pass on a fair share of the benefits to their customers. This feeling persists in spite of the regulation of most, if not all, utilities by boards either appointed by some level of government or elected by a body of voters. The question is one of social concern. The concern can be mitigated by regulators through the application of fair regulatory policies, which depend on a full understanding of the constitution and operation of utilities.

Where the wheeling utilities are state-owned (national, sub-national or municipal) any excess profit of the wheeler automatically accrues to the citizens as owners. Where utilities are investor-owned (IOUs), fairness of the distribution between the undertaking and its customers is less clear cut.

Wheeling is one specific aspect of inter-utility trading. Here, the question may more properly be: can the utilities achieve a pragmatically adequate level of economic efficiency without additional regulation of the wheeling process? The answer is complex and depends on solutions to a host of other problems:

- Do investors have a right to control use of their own property?
- What is a "pragmatically adequate level" of economic efficiency?
- How can conflicts between technical, economic and financial constraints be resolved, when persons in each area have not much sympathy with the others' point of view?
- What happens to the time-hallowed compact between government and utility, which accepted regulation and a responsibility for reliable electricity supply for customers in return for a service monopoly?
- Is the amount in dispute sufficient to warrant intervention by a regulator and how will it be determined when the value has reached a critical level?

It would seem that the determination of the last-mentioned amount should be the first concern. Models are available to calculate benefits of wheeling (See, for instance, Degeneff *et al*, 1985; Huggins and Mirsky, 1985; and Necsulescu and Poirier, 1988.) If it is established that the amount "on the table" is not significant, the rest of the debate, though interesting, is academic.

Conclusion

Wheeling of electric power and energy, i.e., its transport between a buyer and seller through the transmission system of a third-party who does not take ownership of the product, raises questions of technical, financial and economic significance. In the past, suppliers have negotiated contracts among themselves and have achieved many economies through the drive for profitability. The search to use invested capital more fully and the increased social awareness of public bodies have led to questions about the ability of present mechanisms to achieve socially acceptable levels of economic efficiency without extending intervention by regulatory bodies. The debate is ongoing.

The foregoing discussion emphasizes the complexity of the solutions that have evolved in a profit-driven system. It outlines the effect on energy flows and the distribution of benefits that wheeling and the fee structure can have. It proposes that the debate has reached a point where new, hard data are needed to focus attention on the primary question of whether the incremental advantage of further regulatory intervention is worthwhile. Modelling investigations will clarify, but not resolve, the question of the benefits foregone by continuing along the present path. An arbitrator must be found who can fairly justify a resolution of the many problem areas.

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