Electric Power Systems Research 61 (2002) 89–92

www.elsevier.com/locate/epsr

Marginal cost of transmission system adequacy for spot pricing

Oscar Moya *

Department of Electrical Engineering, University of Chile, Av. Tupper 2007, P.O. Box 412-3, Santiago, Chile

Received 23 April 2001; accepted 3 November 2001

Abstract

A model of marginal adequacy costs is developed in order to reflect the influence that any nodal load has on system static security. An adequacy cost function is defined, making use of the load that must be theoretically withdrawn at each node in order to re-establish power flows on transmission elements, after any static contingency of a predefined set occurs. A minimal adequacy transport system is defined as a primary system used as reference for adequacy calculation purposes. Inclusion of adequacy cost function leads to co-ordination equations, which permit identification of marginal costs that are suitable for partial transmission equipment investment recovery. Results of simulations on the reliability test system (RTS) show important costs' components, which are variable in time and space, thus being appropriate for spot pricing schemes. It is verified that a significant part of transmission investment can be recovered by means of the marginal costs of adequacy. © 2002 Published by Elsevier Science B.V.

Keywords: Marginal cost; Transmission system adequacy; Spot pricing

1. Introduction

Transmission services in an open power generation market represent a key point in the definition of the relative advantages of the different generators that are in competition for the electrical demand market [1]. Actually the effect of those services and the way of applying rates to open access users, affect to a significant extent the long term efficiency of the electrical supply process.

There are several advantages of a marginal costing approach, the main of which consists of encouraging investment and operation in the right direction from an efficiency point of view [2].

Identified short-range marginal costs (SRMC) in transmission include mainly losses costs and saturation costs [3]. Some disadvantages of the use of marginal costs have also been pointed out in different studies [4,5].

Alternative means of costing are related to actual investment in transmission assets or to benefit evaluations [6].

Average cost methods such as post stamp schemes, assume that all users connected to the network have to contribute to payment according to a simple parameter such as peak power demand, maximum power injection. Long term costs present serious difficulties arising from economies of scale and different type of externalities [7].

Adequacy plays an important role in transmission system design. Transmission ratings and circuit redundancies are usually oriented to compensate for power flow changes due to element outages. Thus an investment cost is associated to reliability [5] and then should be recovered from users according to participation.

Composite cost, including generation and outage costs, should be used to reflect the optimum operating point in a system [8].

On the other hand, customer reliability worth [9] represents a reference for benefit costing. Marginal investment is associated with a marginal benefit increase. Following this line a marginal cost of transmission directly related to reliability worth marginal cost can be analysed.

Outage costs for different type of users have been identified in terms of power or energy outage costs [10].

This paper presents an approach to adequacy marginal cost determination suitable for complementing spot price determination.

* Fax: + 56-2-695-3881.
E-mail address: osmoya@die.uchile.cl (O. Moya).

PII: S0378-7796(02)00015-9

The hypothesis consists of assuming that adequacy marginal cost can be associated to a short-term cost linked to transmission due to its dependence on the nodal loading, which can be added to the conventional loss-dependent marginal cost. Both components of SRMC can be suitable for transmission investment recovery, thus reducing the need for revenue reconciliation.

Since adequacy changes very strongly with load factor and from one node to another, it is considered that its costs should be recovered on an energy basis.

2. Adequacy marginal cost

System adequacy consists of the ability to supply demand under different conditions and subject to disturbances. The static problem is usually known as adequacy, whereas the dynamic concept is included in security. The latter includes load shedding as a means of keeping service continuity to most consumers and is dependent on spinning reserves, machine inertia constants, line protection, etc.

When adequacy functions are included as costs, they are expected to affect the power system co-ordination equations.

System condition is represented by a composite cost C, which includes economic operational cost and some form of adequacy cost.

$$C(P) = C_{op}(P) + S(P) \tag{1}$$

where C_{op} is the operation cost at condition P, S is the adequacy cost at condition P.

For a power system, the so defined interruption cost depends on the initial loading condition. Any change in this initial condition represents an increment or decrement in the interruption cost. The adequacy cost has sensitivity with respect to operating conditions.

Optimum operation at a system level, including adequacy, is obtained when

$$\delta C/\delta P = \delta C_{op}(P)/\delta P + \delta S(P)/\delta P = 0 \tag{2}$$

The first term of this equation corresponds to the known term of operating cost, mainly dependent on fuel and generator efficiencies. The second term represents the adequacy marginal cost with respect to the operating condition. This element constitutes variation of a benefit received by users, which is similar to the benefit variation involved in generation marginal costs. The adequacy cost term is a systemic function, which should be optimised in the same process of operation cost optimisation.

The above expression can be interpreted as the following fact: a change in operational cost, caused by an increase of load, means also a change in adequacy cost. Optimum condition requires that any load increment that decreases system adequacy i.e. increases adequacy cost, would be expected to reduce operation costs.

Decomposition of elements of the system cost considering nodal generations gives

$$\delta C/\delta P_i = \delta C_{op}/\delta P_i + \lambda(1 - \delta L/\delta P_i) + \delta S(P)/\delta P_i = 0 \tag{3}$$

where P_i is the nodal generation at node i, L is the system losses and λ is the system marginal cost.

A co-ordination condition can be written

$$[\delta C_i/\delta P_i = \delta S(P)/\delta P_i]F_{p_i} = \lambda \tag{4}$$

where F_{p_i} is the classical penalty factor given by

$$F_{p_i} = 1/(1 - \delta L/\delta P_i) \tag{5}$$

Eq. (4) shows that equivalent generator costs are represented by the addition of the generator operating cost and the system adequacy marginal cost with respect to the generator output. Some generators may experience an increase of their equivalent marginal costs when the adequacy marginal cost is positive. The system λ is then higher than the generator production marginal cost. The opposite occurs for negative cost generators. This depends mainly on generator location.

Consumers, on the other hand, have a marginal cost of being supplied obtained in a similar way.

$$Cs_j = \delta C/\delta D_j = \lambda(1 + \delta L/\delta D_j) + \delta S(P)/\delta D_j \tag{6}$$

where D_j is the demand at node j.

This equation indicates that any loads that increase adequacy cost have an additional cost term that refers to adequacy. This not necessarily means a higher rate than in the conventional formulation, since the system λ is also dependent on adequacy terms according to Eq. (4).

The effects of considering an adequacy cost term on marginal cost for both generator and demand nodes have been shown. The effects in practical figures are presented after an adequacy function is derived in Section 3.

3. Adequacy function

The existence of an adequacy function, dependent on generated real powers and demands throughout the system, has been assumed.

The marginal cost of this function must reflect a possible cost incurred when a nodal power is increased by a unit value.

The adequacy marginal cost can be defined as the negative value of a potential marginal interruption cost, which is due to the nodal customer reliability worth.

Designating by I the interruption cost, the marginal adequacy cost can be expressed in terms of reduced nodal powers T_i, outage cost C_i and variations of load P_j: