ABSTRACT.

In distribution system planning, and when designing tariffs and special contracts for both general customers and special large consumers of electrical energy, it is essential to have comprehensive information about the cost structure of the distribution system for different classes of customers and in different locations.

In this paper a comprehensive model is presented to analyse the cost structure of a transmission and distribution system, with either a radial or "network" configuration taking into account multiple electrical power classes. The power system is decomposed into different subsystems and the model is recursive with respect to these subsystems. The model deals with information on subsystem investment and operations costs, loss factors, power peak demand, energy flow, coincidence factors etc. The model calculates unit costs of power and energy for different classes and at different levels in the system, and is based on the philosophy of decomposing costs into energy costs and capacity (power) costs.

The model has been applied to data from a power distribution company in Iceland, where power is purchased from a bulk supplier (The National Power Co.) by 2 separate classes, designated as firm energy and secondary energy. Firm energy is purchased using a block type tariff which can be translated to a tariff with energy and demand charges, while secondary energy purchases are based on a flat energy charge. The model has been programed using a typical spreadsheet personal computer software, and in this application the purpose is to investigate energy cost structure and cost breakdown for firm and secondary energy classes at different locations in the system. To allocate the cost of losses for both energy classes, a special method for measuring secondary energy, utilized for technical reasons, is accounted for in the model. The results include a review of sensitivity and interaction between these firm and secondary energy classes, which is especially valuable, when developing tariffs and/or contracts for special energy intensive customers.

INTRODUCTION.

The power system, as considered for modelling purposes, is assumed to be of a hierarchical nature with electrical power entering the system at the top of the hierarchy and delivered to the customers at various levels in the system. The delivery can be at intermediate or higher level in the system such as for bulk consumers. General low voltage consumer are however assumed to purchase electricity at the lowest level. Levels in the hierarchy are assumed to correspond to some extent to the different voltage levels in the power system.

Distribution system cost studies, reported in the literature, are primarily concerned with design of new system expansions rather than analysing the structure of an existing system. For instance, optimal conductor sizing or selection of components of the distribution system [21, 133] or aggregating data for different utilities, using econometric methods [4] or reporting of different utilities in the U.S. [5] are reported. However in [12] a model of similar nature is presented, but without reference to multiple classes of energy, and without treating a general distribution system hierarchy. Typical monographs and textbook [1], [6], [9], [10], [11] on distribution systems design are also mainly confined with such models.

In this paper we present a model to analyze costs in an existing power distribution system, based on decomposing the total system into subsystem. The purpose is to estimate the energy cost in different locations and levels, where the cost is only allocated to those sections of the distribution system that participate in a certain delivery. The idea behind the decomposition is illustrated in figure 1. The figure shows a typical structure reflecting distribution networks with their subtransmission levels, distribution substation, primary feeders, secondary feeders etc. For instance, the cost of apparatus in subsystem #5 should not contribute to the power cost of delivering energy from, say, subsystem #6.
picture, not strictly a radial configuration. This means that a complicated high voltage transmission systems with “loops” and/or radial configuration can be modeled, if we assume a certain power and energy flow at subsystem boundaries or between subsystems. See also the discussion below relating to the contracting and expanding hierarchy of figure 3.

With this model we analyse how the unit costs of power increases, as power delivery moves into the lower levels of the hierarchy, and thus can analyze actual costs in different geographical parts of the system and at different voltage levels. At each level, the delivery cost has to cover 3 factors:

1. The actual purchasing or generating costs of both power and energy at the entry level of the system, which can either be a single “purchasing point” at the top of the hierarchy or multiple such points at different locations and levels in the system.

2. The cost of all apparatus in all subsystems at intermediate levels between the entry point the delivery point. This factor account for investment costs due to substation equipment, cables and overhead lines and all apparatus associated with the distribution. However, the cost is only allocated to a certain delivery in proportion to the actual amount of transmitted energy and power.

3. Common overhead costs, such as management, billing, operations etc. This cost is allocated to each subsystem or each delivery according to the company philosophy on how common overhead costs should be distributed, or alternatively according to some heuristic rule, for instance as a flat percentage to all delivery costs.

MODEL FORMULATION.

Assume that we have an electrical power distribution system, decomposable into different subsystems, where each subsystem is represented by a box, according to figures 1 and 2. Figure 2 exemplifies a simple system decomposed into 3 subsystems. The system is assumed to distribute different classes of electrical energy, where each class may correspond to different contracts with the bulk supplier and/or customer. The figure assumes 2 such classes, an example which is for instance “firm energy” to be delivered continuously by the bulk supplier and “secondary energy” to be delivered with certain interruption tariff conditions.

At the top of the hierarchy, electrical energy is purchased from the bulk supplier or generated according to a tariff based on, say for each class, annual energy price (cost) and power peak. However it is assumed that the unit cost of transmitting and distributing power and energy is the same for all classes due, of course to the physical properties of the system and it’s transmission characteristics.

Define the following quantities. We distinguish between input quantities (small letters) and output quantities (capital letters) for each subsystem. For information in square brackets, refer to the spreadsheet output in the following section.

\[ i \] Index for subsystem. [Line # 61]
\[ N \] Number of electrical energy classes. [Line # 8 and 10]
\[ p_{ij} \] Power entering subsystem number i of class number j. [Line # 9 and 11].
\[ w_{ij} \] Energy entering subsystem number i of class number j. [Line # 14 and 16].
\[ P_{ij} \] Power delivered out of subsystem number i of class number j. [Line # 15 and 17].
\[ W_{ij} \] Energy delivered out of subsystem number i of class number j. [Line # 12].

\[ q_{pi} \] Loss factor for power in subsystem # i. [Line # 12].

\[ q_{wi} \] Loss factor for energy subsystem # i. [Line # 13].
\[ s_{ij} \] Coincidence factor for an expanding hierarchy for subsystem number i of class j.[Line # 19]
\[ s_{ij}^c \] Coincidence factor for a contracting hierarchy for subsystem number i of class j.
\[ F_i \] Investment cost of all apparatus for subsystem number i.
\[ a \] Annuity factor. [line # 59].
\[ r_i \] Annual operations and maintenance unit cost for subsystem # i. [in monetary units/kW].
\[ f_i \] Annual unit cost for investment, operations, maintenance of subsystem # i. [in e.g. monetary units/kW]. [line # 23].
The following relations can then be established for calculating unit costs at each level in the system. We define the annual unit cost of operating each subsystem as

$$f_i = \frac{\alpha F_i + r_i}{\sum_{j=1}^{N} P_{ij}}$$  \hspace{1cm} (Equation 1)

The total annual cost at the input to each subsystem for each class is by definition:

$$C_{ij} = k_{p_{ij}} p_{ij} + k_{w_{ij}} w_{ij}$$  \hspace{1cm} (Equation 2)

while the total cost at the output of each subsystem, accounting for the subsystem’s own transmission cost, for each class is:

$$C_{ij} = k_{p_{ij}} p_{ij} + k_{w_{ij}} w_{ij} + f_i P_{ij}$$  \hspace{1cm} (Equation 3)

This output cost can be related to output power quantities, since power and energy input and output is related by losses for each subsystem. For each i and j we have, by definition:

$$P_{ij} = q_{pi} P_{ij}$$
$$w_{ij} = q_{wi} W_{ij}$$  \hspace{1cm} (Equation 4)

and therefore for the total cost:

$$C_{ij} = k_{p_{ij}} q_{pi} P_{ij} + k_{w_{ij}} q_{wi} W_{ij} + f_i P_{ij}$$  \hspace{1cm} (Equation 5)

Since, by definition, we have for output quantities:

$$C_{ij} = K_{p_{ij}} P_{ij} + K_{w_{ij}} W_{ij}$$  \hspace{1cm} (Equation 6)

we have, for relating the output and input unit cost of each subsystem:

$$K_{p_{ij}} = k_{p_{ij}} q_{pi} + f_i$$  \hspace{1cm} (Equation 7)

$$K_{w_{ij}} = k_{w_{ij}} q_{wi}$$  \hspace{1cm} (Equation 8)

We can relate subsystem to each other in the radial hierarchy, assuming first the radial expanding hierarchy in figure 2 and figure 3a. We have, by definition of coincidence factors (See for instance [1]), for power quantities:

$$P_{ij} = \sum_{k \in \Pi_i} s_{kj} P_{kj}$$  \hspace{1cm} (Equation 9)

and by conservation of energy for energy quantities

$$W_{ij} = \sum_{k \in \Pi_i} w_{kj}$$  \hspace{1cm} (Equation 10)

We are not interested to relate coincidence factors of different classes to each others, since these classes are assumed to be transmitted and distributed independently.

Substituting equations 9 and 10 into equation number 5, we have:

$$C_{ij} = \sum_{k \in \Pi_i} \left( k_{p_{ij}} q_{pi} s_{kj} P_{kj} + k_{w_{ij}} q_{wi} w_{kj} + f_i s_{kj} P_{kj} \right)$$  \hspace{1cm} (Equation 11)

or:

$$C_{ij} = \sum_{k \in \Pi_i} \left(k_{p_{ij}} q_{pi} s_{kj} + f_i s_{kj} \right) P_{kj} + k_{w_{ij}} q_{wi} w_{kj}$$  \hspace{1cm} (Equation 12)

Therefore unit cost quantities can be interrelated throughout the different levels and subsystems in the hierarchy:

$$k_{p_{kj}} = \left( k_{p_{ij}} q_{pi} + f_i \right) s_{kj}$$
$$k_{w_{kj}} = k_{w_{ij}} q_{wi}$$  \hspace{1cm} (Equation 14)

Above, all cost quantities are allocated either to the power or energy part of the cost. We can however
calculate the average (mean) unit energy cost, by dividing e.g. equation 2 with $w_{ij}$ as:

$$k_{mij} = \frac{k_{p_{ij}} P_{ij}}{W_{ij}} + k_{wij}$$

(Equation 14)

Similarly for output quantities:

$$k_{mij} = \frac{K_{p_{ij}} P_{ij}}{W_{ij}} + K_{wij}$$

(Equation 15)

The above procedures have assumed a decomposition of the system, based on the type of hierarchy of figure 3a. Assume instead a general “network type” hierarchy, where the relationship of individual subsystems to each other can be of the “contracting” type, shown in figure 3b.

Then we get a inverse procedure to the development in equations 1-15. Starting by eq. 6 we can find the total input cost to subsystem #1:

$$c_{ij} = K_{p_{ij}} P_{ij} + K_{wij} W_{ij} - f_{i} P_{i}$$

(Equation 16)

By substituting eq. 4 into eq. 16, we get:

$$c_{ij} = \frac{K_{p_{ij}}}{a_{pi}} P_{ij} + \frac{K_{wij}}{q_{wi}} W_{ij} - \frac{f_{i}}{q_{pi}} P_{ij}$$

(Equation 17)

The following equations are analogous to eq. 9 and 10:

$$P_{ij} = \sum_{k \in \Lambda_{i}} s_{kj} P_{kj}$$

(Equation 18)

$$W_{ij} = \sum_{k \in \Lambda_{i}} W_{kj}$$

(Equation 19)

Further by substituting eq. 18 and 19 into eq 17, we get:

$$c_{ij} = \sum_{k \in \Lambda_{i}} \left( \frac{K_{p_{ij}}}{a_{pi}} - \frac{f_{i}}{q_{pi}} \right) s_{kj} P_{kj} + \frac{K_{wij}}{q_{wi}} W_{kj}$$

(Equation 20)

Similarly to equation 13, the total annual cost at the output of each level in the hierarchy is the same as at the input, next level below.

$$c_{ij} = \sum_{k \in \Lambda_{i}} \left\{ K_{p_{kj}} P_{kj} + K_{wkj} W_{kj} \right\}$$

(Equation 21)

Therefore by comparing eq. 21 and 20 we get the following recursive equation, relating costs for adjacent levels in the hierarchy for subsystems related as in figure 3b.

$$K_{pkj} = \left( \frac{K_{p_{ij}}}{a_{pi}} - \frac{f_{i}}{q_{pi}} \right) s_{kj}$$

$$K_{wkj} = \frac{K_{wij}}{q_{wi}}$$

$$k \in \Lambda_{i}$$

(Equation 22)

Thus it is possible to calculate costs throughout the hierarchy of the type shown in figure 1, using the recursive set of model equations number 14 and 22.

![Figure 4: Akureyri Municipal Electric Works Distribution Subsystem Configuration](image)

**APPLICATIONS OF THE MODEL.**

The above model has been applied to the distribution system of Akureyri Municipal Electrical Works, Akureyri, Iceland. Figure 4 shows the system decomposition, employed in the study. The model was applied using a spreadsheet calculator, and Table A shows typical results from the spreadsheet. Reference to this figure is by common spreadsheet cell identification (e.g.: Cell A21, Line 30 Column c, etc). See also variables definitions in the preceding section.

The study included system breakdown into 7 different subsystems, as indicated in the figure, and involved 2 classes of energy sales ($N=2$), that is *firm energy* and *secondary energy*.

Energy in class 1 (firm) is purchased with a power and energy based tariff (C21 and C22) from the National Power Co. (NPC), the bulk supplier, at the entry level to subsystem number 1. Firm energy is delivered to low voltage customers at the output level of subsystems 4, and 7. Subsystem #5 handles exclusively sales of firm energy to a high voltage customer.

Energy in class 2 (secondary) is purchased with an energy tariff only (B34) and is delivered to a single customer at the output level of subsystem #6, which serves exclusively for this purpose. Thus class 2 energy is transmitted only through subsystems #1, 3 and 6.

The individual subsystems are composed as follows:

1. Subsystem 1 consists of the 60 kV ring network with lines circuit breaker and all 60 kV apparatus.
2. Subsystems 2 and 3 consist of the transformers in substation 1 and 2 respectively with associated gear.

3. Subsystems 4 and 7 consist of all distribution stations in the 6 kV and 11 kV parts of the system, respectively, and the associated low voltage network.

4. Subsystems 5 and 6 consist, each, of one cable to distribution station #31 from distribution substation number 2, and share all other apparatus in that station, such as transformers, meters, etc.

The measurement procedures in this system further complicates the modelling. Measurements of all energy are at the entry level of subsystem #1, while the measurement of the class 2 energy is at the output level of subsystem #6. Therefore the class 1 energy is obtained by subtracting the second measurement from the first, and hence the losses in transmitting the class 2 energy have to be paid for at class 1 prices.

The total cost of purchasing power is:

\[ K_{\text{purchase}} = K_{p62} P_{62} + K_{w62} W_{62} + k_{p11} (P_{11} + P_{12} - P_{62}) + k_{w11} (W_{11} + W_{12} - W_{62}) \]

(Equation 8)

The first 2 factors refer to the purchase price of class 2 energy, while the latter 2 factors denote cost of purchasing class 1 energy. The above equation can be modified:

### TABLE A

An example of a spreadsheet output for the distribution cost model.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Subsystem number</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Firm power input to subsystem (MW)</td>
<td>17.430</td>
<td>12.100</td>
<td>6.380</td>
<td>11996</td>
<td>1.448</td>
<td>5,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Firm energy input to subsystem (MWh/year)</td>
<td>97.549</td>
<td>62.855</td>
<td>32.726</td>
<td>32.614</td>
<td>6.990</td>
<td>25.754</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Secondary power input to subsystem (MW)</td>
<td>3.377</td>
<td>1.308</td>
<td>3.308</td>
<td>3.280</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Load Losses (%)</td>
<td>2.06%</td>
<td>0.87%</td>
<td>0.87%</td>
<td>1.08%</td>
<td>2.93%</td>
<td>7.89%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Energy Losses (%)</td>
<td>2.06%</td>
<td>0.87%</td>
<td>0.87%</td>
<td>7.89%</td>
<td>2.93%</td>
<td>7.89%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Firm energy output from subsystem (MWh/year)</td>
<td>95.981</td>
<td>62.314</td>
<td>32.445</td>
<td>37.803</td>
<td>6.580</td>
<td>23.899</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Secondary power output from subsystem (MWh/year)</td>
<td>3.308</td>
<td>3.280</td>
<td>3.187</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Secondary energy output from subsystem (MWh/year)</td>
<td>11.732</td>
<td>11.631</td>
<td>11.300</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>13. Coincidence factor</td>
<td>1.000</td>
<td>0.928</td>
<td>0.928</td>
<td>1.000</td>
<td>0.969</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Firm input unit cost, (krW)</td>
<td>6.33</td>
<td>6.33</td>
<td>6.33</td>
<td>8.34</td>
<td>0.34</td>
<td>0.34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Firm output unit energy (MWh/year)</td>
<td>0.41</td>
<td>0.34</td>
<td>0.34</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Total Firm annual cost (Mkr/year)</td>
<td>151.929</td>
<td>101.728</td>
<td>53.324</td>
<td>135.689</td>
<td>135.689</td>
<td>135.689</td>
<td>0.000</td>
<td>59.567</td>
<td></td>
</tr>
<tr>
<td>20. Unit firm output (kW)</td>
<td>1.48</td>
<td>1.59</td>
<td>1.59</td>
<td>1.63</td>
<td>1.76</td>
<td>1.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Unit firm input (kW)</td>
<td>1.59</td>
<td>1.63</td>
<td>1.64</td>
<td>2.35</td>
<td>2.11</td>
<td>2.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. T&amp;D firm energy unit cost (kW)</td>
<td>0.11</td>
<td>0.15</td>
<td>0.16</td>
<td>0.36</td>
<td>0.63</td>
<td>1.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Unit Cost Matrix

<table>
<thead>
<tr>
<th>Unit Cost (kWh/year)</th>
<th>Total Cost (Mkr/year)</th>
<th>Unit Cost Factor</th>
<th>Energy Value</th>
<th>AmountUnit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Underground Cable (Mkr)</td>
<td>94.269</td>
<td>40.900</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>2. Distribution Stations (Mkr)</td>
<td>233.750</td>
<td>167.750</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>3. Number of Distribution Stations</td>
<td>82.0</td>
<td>61.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4. High Voltage Gear (Mkr)</td>
<td>65.720</td>
<td>6.000</td>
<td>18.000</td>
<td>1.360</td>
</tr>
<tr>
<td>5. Low Voltage Gear (Mkr)</td>
<td>197.000</td>
<td>197.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>6. Total Investment Cost (Mkr)</td>
<td>590.719</td>
<td>590.719</td>
<td>590.719</td>
<td>590.719</td>
</tr>
<tr>
<td>7. Operations Cost and fraction of imports</td>
<td>1.5%</td>
<td>1.5%</td>
<td>1.5%</td>
<td>1.5%</td>
</tr>
<tr>
<td>8. Ov儿 loads and management Cost (Mkr)</td>
<td>500.0</td>
<td>500.0</td>
<td>500.0</td>
<td>500.0</td>
</tr>
<tr>
<td>9. Annual Operations cost (Mkr/kWh)</td>
<td>8.663</td>
<td>0.908</td>
<td>1.208</td>
<td>1.08</td>
</tr>
<tr>
<td>10. Annual Maintenance cost (Mkr)</td>
<td>41.912</td>
<td>4.293</td>
<td>1.127</td>
<td>1.277</td>
</tr>
<tr>
<td>11. Overhead and Management Cost (Mkr)</td>
<td>15.740</td>
<td>1.346</td>
<td>1.357</td>
<td>1.357</td>
</tr>
<tr>
<td>12. Overhead and Management Cost (Mkr)</td>
<td>0.2864</td>
<td>0.2864</td>
<td>0.2864</td>
<td>0.2864</td>
</tr>
<tr>
<td>13. Annual Cost (Mkr)</td>
<td>68.504</td>
<td>8.632</td>
<td>1.818</td>
<td>1.990</td>
</tr>
<tr>
<td>14. Annual factor</td>
<td>7.095%</td>
<td>35.763</td>
<td>0.950%</td>
<td>0.950%</td>
</tr>
<tr>
<td>15. Total Overhead Cost (Mkr)</td>
<td>15.735</td>
<td>0.2864</td>
<td>0.2864</td>
<td>0.2864</td>
</tr>
<tr>
<td>16. Total other Costs (Mkr)</td>
<td>2.000</td>
<td>2.000</td>
<td>2.000</td>
<td>2.000</td>
</tr>
</tbody>
</table>

### Summary

- **Annual interest rate (5.000%)**: 217.645
- **Depreciation Period (yr)**: 25
\[ K_{\text{purchase}} = (K_{p62}P_{62} + K_{w62}W_{62}) + \left( k_{p11}P_{11} - P_{62} \right) + k_{w11}(W_{11} - W_{62}) \]

\[ + \left( k_{p11}P_{12} + k_{w11}W_{12} \right) \]

(Equation 9)

The first factor (parentheses) refers to the cost of purchasing class 2 energy at the output level of subsystem 6 (line 34, columns B-E). The second factor is the cost of losses to transmit the class 2 energy (lines 36, 37, 38, columns B-E) and the third factor accounts for the purchasing of all class 1 energy. It is therefore logical to allocate the cost of losses for class 2 energy to the class 2 delivery, even though it is paid for at class 1 prices.

RESULTS AND DISCUSSIONS.

We make the following comments regarding the application of the model to the Akureyri system:

1. The monetary units shown are Icelandic krónur (kr). The rate of exchange is approximately 1 US Dollar = 45 kronur. The amounts shown are solely for illustration purposes and do not constitute a statement of actual costs in the Akureyri system.

2. The model accounts for the following cost factors:
   a. The cost of purchasing power from the bulk supplier.
   b. Construction cost of HV cables and overhead lines.
   c. Construction cost of distribution stations.
   d. Construction cost of distribution substations with all electrical apparatus.
   e. An estimate of all construction cost of low voltage system.
   f. Operations and maintenance cost of the system.
   g. Common management costs, billing, interest payments, offices, technical support etc.

3. Losses (lines 12 and 13) and coincidence factors were estimated using data from Akureyri Municipal Electrical Works [8] and to some extent based on previous estimates in the Icelandic power system [7].

4. Values for power flow between subsystems is based on information from Akureyri Municipal Electrical Works ([8] and personal communications with Mr. S. Sigurðsson).

Figure 5
Akureyri Municipal Electrical Power Distribution System

Legend:
- 60 kV Circuit breaker
- 6 kV/11 kV Circuit breaker
- Distribution station (number 49)

(Disconnection not shown)
5. The estimate of unit average cost of class 1 energy differs, of course, for individual subsystems. Cells F29 and 129, for instance, show these costs for low voltage customers. The average cost for the whole system is however shown in cells J34-36.

We have above presented a comprehensive mathematical model, which should be useful for many purposes when analysing power systems cost structure.

First it can be used to obtain a picture of “actual” costs in different geographical locations in the system and compare these costs to prices when for instance designing tariffs. Assume that for political or other purposes, it is decided to have the same tariff in all parts of the system, an arrangement common within an electrical utility. The above model can be used to estimate the geographical distribution of the necessary subsidies to obtain the above equalization of costs.

Secondly, it may be desirable to be able to negotiate a special contract with industrial customers, located at strategic locations in the system. Then such a model can act as a guideline as to what cost range is feasible in such negotiations.

Thirdly, it is possible that the system is to be viewed geographically as one subsystem, for instance to obtain the equalization of costs, as discussed above, but an estimate is needed on the appropriate weight of the demand charges (power) and energy charges, respectively to individual customers or in individual tariff classes. This model could in such a case be a vehicle for analysing the effect of coincidence factors, losses and other costs in the power distribution system.

Finally, it shall be mentioned that several extensions of the model are possible to acquire a more accurate and comprehensive model of the power system cost structure. We will name only two.

First it is possible to model the losses more accurately, since power losses, as is well known, are in general higher than energy losses.

Secondly, it is possible to introduce the concept of load factor, or equivalently annual utilization time, into the model, although it will not expand the principle of the model.

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REFERENCES:


