C O N S U L T A T I O N D O C U M E N T

INCENTIVE MECHANISMS FOR MANAGING TRANSMISSION & DISTRIBUTION LOSSES

(Trinidad and Tobago Electricity Commission (T&TEC))

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1. INTRODUCTION

1.1 Background

The Regulated Industries Commission (RIC) is required under its Act (No. 26 of 1998) **to** set price controls for the service providers under its purview. In making its determination, the Act emphasizes the adoption of the incentive regulation/price cap regulation. The distinguishing feature of this form of regulation is the emphasis it places on the provision of incentives to improve efficiency of operations. The package of incentives offered to service providers will influence the way they utilize their existing assets and make investment decisions over the short, medium and long-term.

Electrical losses are an inevitable consequence of the transfer of energy across transmission and distribution (T&D) networks. The costs of losses on the network are ultimately borne by the final consumer. It is important therefore, to ensure that losses are kept to the lowest level possible. T&D system losses for T&TEC averaged about 8% over the period 1999-2003 and the reduction of these losses will constitute a fairly significant source of efficiency gain. The level of losses is influenced by both technical and operational factors. It is important therefore, that the service provider receives appropriate incentives to manage these factors and thus optimize the level of losses in the most efficient and effective way. Currently, the regulatory regime does not provide incentives to encourage T&TEC to optimize system losses.

1.2 Purpose of Document

The main purpose of this document is to consider different incentive mechanisms to encourage the service provider to optimize system losses. Additionally, comments and views of stakeholders on the issues raised in the document are invited.

1.3 Structure of this Document

The remainder of the document is structured as follows:

Section 2 examines categories of system losses, loss reduction possibilities, and the extent to which the utility can influence the level of losses.

Section 3 explores the factors that need to be considered in designing an incentive framework and different incentive options.

Section 4 provides overall conclusions and summarises the issues for consultation

2. LEVEL OF LOSSES AND REDUCTION POSSIBILITIES

The Transmission and Distribution network comprises overhead lines, cables, transformers, switchgear and other equipment to facilitate the transportation of electricity to consumers. Most consumers are supplied at low voltage (LV), usually less than 600V. Larger commercial and industrial customers are typically supplied at high voltage (HV), that is, between 600 V and 12kV, with very large customers supplied at voltages of 12kV or greater.

Energy is carried from **the** generating station through the transmission and distribution network. In the process of supplying electricity to consumers, some power is consumed or dissipated in stepping up or stepping down the voltage levels, and some is lost along the lines and cables that carry the energy. Losses occurring at various stages of power transformation and loading of the transmission system at 132,000 volts (132kV) and 66,000 volts (66kV) are known as transmission losses, whereas losses occurring at 33,000 volts (33kV) are known as sub-transmission losses. The losses at the 12kV, 6.6kV and lower voltage levels are termed distribution losses. The transmission and distribution losses associated with the operation of the network are classified as technical and non-technical losses.

2.1 Technical Losses

Technical losses generally vary with the square of the load current being distributed. As a result, losses will increase as more capacity is used. Losses are also proportional to the length of the line.

The technical losses comprise both variable and fixed components. The fixed component of technical losses depends largely on the system configuration, pattern of loading of transmission and distribution lines, magnitude and types of loads, characteristics of equipment etc. The variable component is due to weak and inadequate sub-transmission and distribution lines, inadequate sizing of conductors used, lengthy transmission and distribution lines and inadequate reactive compensation in the system.

2.2 Non-Technical (Commercial) Losses

The non-technical losses are a component of distribution system losses that are not related to the physical characteristics and functions of the electrical system. They are associated with unidentified and uncollected revenue, arising from consumer fraud (meter tampering, illegal connections), metering errors, shortfalls in billing and revenue collection.

In an attempt to properly account for total system losses, the electric energy used by the transmission and distribution utility is separately identified (sometimes referred to administrative loss). It includes the electric energy consumed by electrical loads in the facilities such as substations, offices, warehouses and workshops of the utility.

2.3 Measuring Losses

Comparisons between networks of different countries are not straightforward, and it is difficult to define an optimal or efficient level of losses for a network because of some important differences, including:

- number of customers connected to the network;
- quantity of electricity distributed;
- degree of dispersion of customers across the network;
- proportion of different types of customers connected to the network;
- geographical size of the area being covered;
- the amount of underground cables compared to overhead lines; and
- voltage transformation levels.

Furthermore, networks adopt different design, operating and investment principles, thus leading to different network configurations. Given the long lives of network assets, the losses may be optimal considering past investment decisions, but higher than the long-term goal.

The assessment of losses is dependent on **the** accuracy of measurement[1]. An inherent difficulty is obtaining data on unmetered supplies and theft. Another factor is the accuracy with which unmetered supplies (including street lighting) are estimated. Moreover, different countries may adopt different methods for calculating losses.

Transmission and distribution system losses are generally defined as a percentage of the difference between total energy input to the network and sales to all customers. Other jurisdictions have defined total losses as total energy purchased minus the sum of the total annual sales of energy and own usage. Furthermore, there are other jurisdictions which calculate losses as the difference between the units input and units realized (units billed and collected). These methods lump all technical and non-technical losses together. For the accurate measurement of technical losses on the transmission and distribution systems, it is essential to install metering equipment at each voltage level of transmission and transformation. Transmission and Distribution loss levels for some countries are listed in **Table 1**.

[1] Through bulk supply point metering, the measurement of technical losses can be quite accurate.

Table 1. Transmission and Distribution Losses in Selected Countries

Country	% Losses (2000)	Country	% Losses (2000)
Finland	3.7	Sweden	9.1
Netherlands	4.2	Australia	9.1
Belgium	4.8	U.K.	9.4
Germany	5.1	Portugal	9.4
Italy	7.0	Norway	9.8
Denmark	7.1	Ireland	9.9
USA	7.1	Canada	9.9
Switzerland	7.4	Botswana (2002)	10.0
France	7.8	Spain	10.6
Austria	7.8	New Zealand	11.5
Trinidad and Tobago (‘99 –’03 Ave.)	7.9	Jamaica (2003)	18.8

T&TEC’s level of system losses for the period 1999 to 2003 are presented in Table 2. Given that economic loss levels tend to be system-specific, the overall loss level of T&TEC would appear to compare favourably with most other jurisdictions[2]. However, **as** can be observed from **Table 2**, there are significant variations from year-to-year. The RIC is of the view that the losses of any kind (technical, non-technical or non-realization of payments) ultimately result in loss in revenues. Efficiency gains must embrace all these aspects. **Hence, the RIC feels that the clearest measure of overall efficiency of the network is the difference between units input into the system and the units for which the payment is collected. Consequently, method 3 shown in Table 2 shall be the basis for computation of incentives for better performance.**

[2] While economic loss levels for networks will vary with load factors, loss factors and costs, the economic loss levels for **distribution**, according to World Bank data, are in the general range of:

- 3 to 5% of annual energy; and
- 5 to 8% of power at peak.

Economic loss levels for **transmission** are likely to be in the 2 to 3% range (annual energy).

<u>Table 2. Calculation of T&TEC's System Losses, 1999 – 2003</u>

	%					
Method Utilized	**1999**	**2000**	**2001**	**2002**	**2003**	**5 yr Average**
1. $\frac{\text{Energy Input} - \text{Sales}}{\text{Energy Input}}$	5.7	7.3	10.9	7.6	4.8	7.3
2. $\frac{\text{Energy Input} - (\text{Sales} + \text{Own Use})}{\text{Energy Input}}$	5.5	7.2	10.7	7.5	4.6	7.1
3. $1 - \frac{\text{Units Billed}}{\text{Units Purchased}} \times \frac{\text{Collection (\$)}}{\text{Billing (\$)}}$	6.3	7.7	10.7	8.0	6.9	7.9

Source: T&TEC data.

The RIC invites comments on:

- ***the most appropriate method for calculating total system losses for T&TEC; and***
- ***the optimal level of losses for T&TEC.***

2.4 <u>Cost of Losses and Accounting Losses in Tariffs</u>

Losses result in considerable financial and environmental costs. The financial value of the losses varies by time of day and time of year, as during periods of high demand unit prices are higher and capacity requirements are greater. Such financial costs are borne by customers.

The critical decision for a regulator therefore is how to account for losses in fixing tariffs for customers. The most common regulatory approach is to include a **"grossing up"** factor (loss adjustment factor) in the tariff setting formula. If a transmission and distribution network buys 100 units of electricity and the system losses are 8%, then the regulator would allow the transmission and distribution entity the cost of acquiring 108 units of electricity in tariffs. Over time, the regulator would want to reduce the **"gross up"** element so that the utility will have an incentive to reduce losses. The target for loss reduction used by some regulators focuses on technical and commercial losses (T&C losses) where the formula measures technical, commercial and collection losses (i.e. kWh purchased and kWh realized from retail customers), while other regulators may not include collection losses. This narrower definition of losses requires accurate metering. Technical and commercial losses, however defined, affect allowed tariff levels through a two-step process as shown below:

Step 1 – Calculation of T&C

$$\text{T\&C} = 1 - \left\{ \frac{\text{Energy Units Billed}}{\text{Energy Units Purchased}} \times \frac{\text{Collection in \$}}{\text{Billing in \$}} \right\}$$

Step 2 – Gross-up Calculation

$$\text{Allowed Units of power purchased} = \frac{1}{1 - \text{T\&C}}$$

The level of losses therefore has a direct impact on the price of electricity consumed. The cost of losses is generally spread out over all users.

Based on T&TEC's information, the average cost[3] per kWh of energy was estimated to be about TT$0.1275 for the period 1999 to 2003. Using this figure, the average annual cost of total system losses is calculated as $52.7 million per year for the period 1999 to

[3] Losses should generally be valued at the long run marginal cost (LRMC) of power and energy at the point in question on the network.

2003. For example, in 2002, when losses of 8.0% were recorded, a 0.5% reduction in total system losses would have saved T&TEC $3.7 million. The cost of total system losses to T&TEC for the period 1999 to 2003 are presented in Table 3. **It must be noted** that the full cost of technical losses on a network consists of not only the value of the electricity lost, but also the cost of providing the additional transportation capacity and the cost of the environmental impacts associated with the additional generation that is needed to cover losses.

Table 3. Cost of System Losses, 1999 - 2003

YEAR	TOTAL SYSTEM LOSSES (MWH)	COST (TT$MILLION)
1999	294,961	37.608
2000	396,552	50.560
2001	609,116	77.662
2002	464,697	59.249
2003	304,104	38.773

2.5 Loss Reduction Possibilities

The level of losses on a network is influenced by a number of factors. The utility's ability to control these, as well as the associated costs, will largely determine the scope for the incentive mechanism to reduce losses. It is important therefore, that the incentives for loss reduction are set so that the utility makes an appropriate effort to reduce losses.

The recorded losses can be broken down into three main groups:

- ***Variable losses* –** these occur mainly in lines and cables and in the copper parts of transformers and vary in the amount of electricity that is transported through the equipment.
- ***Fixed losses*** – these occur mainly in the transformer cores and do not vary according to electrical current. Both variable and fixed losses are technical losses.

- ***Non-technical losses*** - these comprise of units that are delivered and consumed but for some reasons are not recorded as sales.

As indicated above, variable losses vary with the amount of electricity distributed and are proportional to the square of the current. Between 2/3 and 3/4 of technical losses are variable. **Variable losses** can be influenced in a number of ways:

- ***Utilization of Capacity*** - increasing the cross sectional area of lines and cables for a given load will lower losses but there will be a trade-off between cost of losses and cost of capital expenditure.
- ***Higher Voltages*** - moving to higher voltages reduces utilization and therefore losses in the networks.
- ***Shorter and more direct lines*** - there is scope for reducing losses by reconfiguring the network, for example by providing more direct lines to where demand is currently situated.
- ***Demand management*** - reducing peaks in demand can reduce losses. An additional demand of 1 GW in peak times will result in a greater increase in losses than 1 GW in off-peak periods.
- ***Balancing 3 phase loads*** **-** balancing 3 phase loads periodically throughout a network, especially overhead line networks, can reduce losses significantly.

Fixed losses on a network can also be influenced in a number of ways, including:

- ***Quality of transformer core material*** - the level of fixed losses in a transformer is largely dependent on the quantity and quality of the raw material in the core. Therefore higher quality materials will lead to lower losses.
- ***Eliminating transformation levels*** - eliminating 33 kV transformation levels and moving to 66kV voltage levels can reduce losses. Switching off transformers in periods of low demand can also lead to lower losses.

Non-technical losses – can also be lowered in a number of ways, such as:

- ***Elimination/Reduction of Meter errors*** - the introduction of modern electronic meters can reduce the likelihood of meter errors.

- ***Eliminating Measurement errors in the settlement system*** **–** the method of estimating customer's consumption can distort the recorded losses and therefore improvements in the method of estimating consumption can lower losses.
- ***Closer monitoring of unmetered supplies*** - for practical reasons, some electrical installations, such as street lighting are not metered. In some instances, photocell **controlled** streetlights may not work, thereby not allowing them to be switched off during daylight hours. Improvements in these areas will help reduce losses.
- ***Curbing the Illegal abstraction of electricity*** - this mainly consists of meter tampering and illegal connections. Although it is not possible to gauge the exact extent of illegal abstraction, T&TEC has been able to identify a few areas where such activities occur.

Distributed (embedded) generation, i.e. locating generation close to demand, can also reduce losses as the distances over which electricity is transported may be shortened, and the number of voltage transformation levels this supply undergoes is lessened. Measures to optimize levels of system losses are presented in **Appendix 1.**

The RIC invites comments on the suggested methods and any other areas in which losses may be reduced.

3. DESIGNING AN INCENTIVE FRAMEWORK

Loss reduction is a difficult and time-consuming process, requiring investment, good management systems, vigilance, proper legislation and regulation. However, without any regulatory intervention, there would be weak incentives to reduce losses to an optimal level[4]. At the same time, it is important that the incentive is sufficiently strong to encourage the service provider to reduce losses. The incentive should not be too strong or too weak. The question which arises is, how should a network operator be encouraged to reduce losses?

[4] Costs of losses are unlikely to be a prime driver for asset replacement but may be a contributory factor in bringing forward the replacement of a high-loss transformer, for example.

Generally, regulatory approaches for reducing losses are either based on "command and control rules" or incentive based. Command and control rules prohibit or discourage the utility from undertaking a specified objectionable practice by the threat of a monetary penalty. An incentive-based approach attempts to change a utility's behaviour through explicit monetary rewards and penalties across different levels of actual performance.

3.1 Alternative Incentive Schemes

A variety of mechanisms is used for incentivising loss reduction but two commonly proposed are:

(1) Any **increase** in revenue that **is** not associated with an increase in electricity purchase by the utility is allowed to be kept as **higher profit.**

(2) A separate item relating to measured losses is introduced into the price control formula whereby losses are directly calculated and incorporated into the model.

The form of control under **option 1** may be expressed as follows:

$$TG_t^f = \left[(S_t^f \times G_t^f) \times (1 + l_t^f) \right]$$

Where:

TG	=	total generation cost
S	=	sales
G	=	generation price per kwh
l	=	proportion of losses
f	=	forecast figure
t	=	time (year)

Any divergence in actual total generation not explained by a divergence in the elements of the formula is assumed to be due to a change in losses. It is therefore possible to estimate the losses that actually occur by solving the above equation, that is,

$$l_t^a = \left(\frac{TG_t^a}{S_t^a \times G_t^a} \right) - 1$$

Where 'a' denotes an actual figure.

The impact of the change in losses (l) can then be estimated and the utility is rewarded accordingly**, that is,**

$$l_t = (l_t^f - l_t^a) \times (S_t^f \times G_t^f)$$

This approach relies on information reported by the utility, and the utility may also receive rewards for demand increases. The incentive for loss reduction is high as the utility effectively keeps the generation cost per unit of electricity. However, the regulator can demand that the benefits be shared.

The **second approach** would be to treat with the losses directly by including it in the price control formula[5], that is,

$$MAR_{t+1} = MAR_t \times [\, 1 + RPI - X \,] + l_t$$

[5] The loss adjustment factor l is given by:

$l = (Z_a - Z_c) \times (RPC \times Mwh)$

Where:

Z_a = Average of Percentage losses for the previous 5 years of the regulatory period

Z_c = Percentage losses for the current year

RPC = Regulated passthrough price ($per Mwh)

Mwh = Metered energy purchases in the current year.

Where MAR = Maximum annual revenue. This is subject to an annual efficiency improvement of [1 + RPI – X].

Here, losses are directly included as a controllable cost, with benefits due to reductions in losses over the forecast figure being kept by the utility and excess costs above the forecast being borne by the utility. The formula provides an increment to the revenue to the extent that a utility succeeds in making the current year losses less than the average of the previous 5 years (i.e. if the regulatory control period is 5 years). The main criticisms of this approach are that it:

- requires an accurate measure of losses;
- provides inadequate incentive for loss reduction investment; and
- seems to impose a penalty on a utility which improves efficiency through increased asset utilization.

3.2 Structuring Rewards for Reduction in System Losses

There are other **less formal approaches** to structuring of rewards to encourage reduction in system losses, including:

Option 1 - Accepting system losses as **declared** by the utility and **including the figure** in the revenue requirement, **then** providing a predetermined incentive for improvements or a penalty for non-achievement above or below that level of losses.

Option 2 - Accepting **target** system loss level, and any improvement/shortfall (i.e. target less actual) constitutes incentive and if vice versa, a penalty. The target is set at the beginning of the control period for the entire regulatory control period. If the actual system loss is less than target, the utility gains the entire difference as incentive, without any cap. If the actual loss is higher than target, the utility bears the entire difference as penalty, without any safety net.

<u>Option 3</u> - Accepting as the target, a system loss level equal to a **moving average** of the past 5 years' actual loss level, and any improvement/shortfall (i.e. target less actual) is an incentive and if vice versa, a penalty. The target here is not set **upfront** but evolves with time. The interpretation of outcomes is the same as for option 2. The incentive/penalty arises from the natural lag of a moving average.

<u>Option 4</u> - Under this option, the system losses at the **present level are fixed** for deriving the revenue requirement for the entire control period. Thereafter, if the regulator is assured by evidence of a reduction in system losses, tighter targets could be written in for the next control period.

3.3 Output- Versus Input-Based Incentive Mechanisms

The above methods are output-based incentive methods, where a fixed benefit is provided for reducing losses. It has been argued that the incentives should be placed on inputs rather than outputs. By estimating the contribution to loss reduction from a particular piece of equipment compared to the one most commonly installed, the utility could be given this amount to encourage the installation of such equipment. This would avoid the problem of measuring losses and instead the number of transformers installed in a year would need to be recorded.

An advantage of such a scheme is that all the benefits from reducing losses are given in the same year as when the equipment is installed, thereby reducing any uncertainty regarding future incentives.

However, there are some serious limitations of input-based incentive schemes. Firstly, it would be necessary to assess a wide range and a large number of models of equipment and, only then, form a judgment as to the most suitable equipment for reducing losses. Secondly, the measure of reduction in losses attributable to any kind of equipment may be difficult to calculate. Finally, the input-based incentive mechanism assumes that reductions in non-technical losses should not be incentivised. Because of these main limitations, an output-based mechanism has generally been preferred over input based.

The RIC invites comments on the following:

- ***important factors in assessing the merits and demerits of alternative incentive schemes;***
- ***the merits and demerits of the alternative options for incentivising losses;***
- ***the appropriateness of introducing an incentive scheme that differentiates variable, fixed and non-technical losses; and***
- ***the level of sharing, if any, that should be applied to the savings made by T&TEC in the event of the reduction of losses below the targeted figure.***

4. CONCLUSION AND ISSUES FOR CONSULTATION

4.1 Overall Conclusions

It is clear that systems for the measurement of losses need to be sufficiently robust to ensure proper rewarding of loss reduction initiatives, otherwise unearned benefits might ensue due to the empirical nature of assessment of losses or due to inaccurate assumptions about the benefits of loss reduction programmes. There is also a trade-off between investment and losses and, if the costs of both are not truly reflected, identification of optimum system operating conditions may prove elusive.

Notwithstanding, the regulatory regime should provide incentives to influence T&TEC to optimize network costs, including system losses. Within realistic limits, loss reduction can be a cheaper alternative than adding new network capacity.

4.2 Issues for Consultation

Views are invited on the issues raised in this document and in particular on the following:

- Areas in which losses can be reduced.
- The optimal level of losses for T&TEC.
- The most appropriate method for calculating total system losses for T&TEC.
- The important factors in assessing the merits and demerits of alternative incentive schemes.
- The merits and demerits of the alternative options for incentivising losses.
- Appropriateness of introducing an incentive scheme that differentiates variable, fixed and non-technical losses.
- The level of sharing, if any, that should be applied to the savings made by T&TEC in the event of the reduction of losses below the targeted figure.

APPENDIX I

MEASURES TO OPTIMIZE LEVELS OF SYSTEM LOSSES

Technical measures that can be employed to optimize system losses:

- Loss reduction on the primary distribution system should include power factor correction using capacitors, re-conductoring of old feeders, construction of new feeders, switching load between feeders.

- The use of Low-loss transformers (i.e. low fixed or magnetizing loss) – particularly in the case of distribution transformers.

- Re-conductor overhead lines with larger cross-sectional area conductors; use of lower resistance conductors such as all aluminium alloy conductor.

- Installation of cables having larger conductor sizes.

- Use of cables and capacitors with lower dielectric losses.

- The use of a higher sub-transmission system voltage further into the network, alternatively (and where possible) upgrading of 12 kV networks to 22 kV networks.

- Reactive power compensation (in practice the installation of (generally switched) shunt capacitor banks, either at substations or on the network (pole top capacitors)).

- Tariffs with maximum demand and/or power factor clauses for medium and large customers thereby encouraging power factor correction at source.

- Reconfiguration (of normally open points) of HV feeders to reduce system losses, commensurate with other operational requirements.

- Balancing of load between phases on feeders.

- Load shifting (e.g. reduction of maximum demand through off-peak tariffs).

- Use of energy efficient lighting.

A new development in the United States is the amorphous core distribution transformer with very low fixed losses but higher costs than conventional units. Amorphous core distribution transformers are invariably single-phase units.