Key Drivers and Economic Impact of Non-Technical Losses in Distribution Power Systems: Experiences in Latin America

by

Alberto Elizalde, Energy Specialist
Inter-American Development Bank, Energy Division
Representative Office in Venezuela, Edif. Banco Bicentenario, Av. Venezuela, Caracas, Venezuela
Phone: +58 2 12 955 29 57, Email: albertoel@iadb.org

The opinions expressed in this publication are those of the author and do not necessarily reflect the views of the Inter-American Development Bank, its Board of Directors, or the Technical Advisors.

Abstract

An important measure of the performance of a transmission and distribution system is the fraction of energy generated that is lost due to heating of transmission and distribution lines and of other components (technical) and to theft and others practices (non-technical). Losses are measured as the difference between energy generated and energy delivered to consumers. The objective of this paper is to examine key drivers and economic impact of non-technical losses in distribution power systems in the Latin American region. The paper is organized as follows. After the introduction, the second section gives a brief overview of losses in transmission and distribution power systems in selected countries in the World and Latin America (LAC). The third section addresses some key drivers that have determined current loss levels in LAC. In section four, we explore economic impact of losses on the electricity sector in the region.

1. Introduction

An important measure of the performance of a transmission and distribution system is the fraction of energy generated that is lost due to heating of transmission and distribution lines and of other components (technical) and to theft and others practices (non-technical). Losses are measured as the difference between energy generated and energy delivered to consumers.

In literature, we can find three different types of losses that are encountered in power systems (Kirschen D. and G. Strbac, 2004).

Variable losses. They are caused by the current flowing through the lines, cables and transformers of the network and are also called load losses, series losses, copper losses or transport-related losses. They are proportional to the resistance of the branch and to the square of the current in this branch.

Fixed losses. Most of these losses are caused by hysteresis and eddy current losses in the iron core of the transformers. The rest is due to the corona effect in transmission lines. Fixed losses are proportional to the square of the voltage and independent of the power flows. However, since the voltage varies relatively little from its nominal value, as a first approximation, these losses can be treated as constant. They are also called no-load losses, shunt losses or iron losses.

The two previous types are usually called technical losses.

Non-technical losses. This euphemism covers energy that is stolen from the power system.

Because of their quadratic dependence on the power flows, variable losses are much more significant during periods of peak load and typically much larger than fixed losses. Averaged over a whole year, in western European countries, 1 to 3 % of the energy produced is lost in the transmission system and 4 to 9% in the distribution system.
Non-technical losses are not considered to be important in developed countries today, but they are significant in developing countries. The objective of this paper is to examine key drivers and economic impact of non-technical losses in distribution power systems in the Latin American region.

The paper is organized as follows. After the introduction, the second section gives a brief overview about losses in transmission and distribution power systems in selected countries in the World and Latin America (LAC). The third section addresses some key drivers that have determined current loss levels in LAC. In section four, we explore economic impact derived of this evolution.

2. Losses in Transmission and Distribution Power Systems in Selected Countries in the World and Latin America

First of all, we analyzed historical evolution of losses in transmission and distribution systems in some Developed Countries (DEC) and LAC.

2.1 United States, France, South Korea and other DEC

The USA has observed a decreasing trend from 1960 reaching 6% of losses last years (Figure 1). Losses in France are similar to the USA (Figure 2). South Korea has one of the lowest loss levels in the world with only 4% (Figure 3). Figure 4 shows evolution of losses in selected DEC, which oscillate between 4 and 8%. For this group of countries, South Korea leads this indicator and Canada has the highest level (8%).

![Figure 1. Transmission and Distribution Losses in the United States, 1960-2009](source: World Bank Development Indicators, http://data.worldbank.org/indicator)
Figure 2. Transmission and Distribution Losses in France, 1960-2009

Figure 3. Transmission and Distribution Losses in South Korea, 1971-2009
Transmission and Distribution Losses (\% of total generation)

United States
South Korea
France
Japan
Germany
China
United Kingdom
Canada


Figure 4. Transmission and Distribution Losses in Developed Countries, 1971-2009

2.2 In Latin America

We started this analysis with Brazil whose losses were stable during 70’s (12\%). Since mid-80’s, they have been raising to levels well in line with the 14 \% average for the LAC region (Figure 5). Mexico has increased losses since mid-80 as shown in Figure 6. Argentina has followed a raising trend until early 90’s and then a decreasing pattern (Figure 7). Chile is the best ranked country in the region (less than 10\% of losses) (Figure 8). Venezuela’s figures show that losses have climbed to more than 25 \% (Figure 9). Colombia, Nicaragua and Panamá have exhibited a growing-decreasing trend (Figures 10, 11 and 12). Costa Rica’s losses remain in “good” performance (around 10\%) (Figure 13).


Figure 5. Transmission and Distribution Losses in Brazil, 1971-2009
Mexico


Figure 6. Transmission and Distribution Losses in Mexico, 1971-2009

Argentina


Figure 7. Transmission and Distribution Losses in Argentina, 1971-2009
Figure 8. Transmission and Distribution Losses in Chile, 1971-2009


Figure 9. Transmission and Distribution Losses in Venezuela, 1971-2009

Figure 10. Transmission and Distribution Losses in Colombia, 1971-2009

Figure 11. Transmission and Distribution Losses in Nicaragua, 1971-2009
Figure 12. Transmission and Distribution Losses in Panama, 1971-2009

Figure 13. Transmission and Distribution Losses in Costa Rica, 1971-2009

Figures 14 and 15 show the historical evolution of transmission and distribution losses in LAC and selected countries for the period 1971-2009, respectively.

![Figure 14. Transmission and Distribution Losses in Latin America, 1971-2009](source)

![Figure 15. Transmission and Distribution Losses in selected countries, 1971-2009](source)

3. Some Key Drivers of Losses in Latin America

International experiences show that losses tend to decline somewhat with increasing population density, economic development and private participation in utilities all else equal, as one would expect. We evaluated these three variables in some LAC and results are presented below.
3.1 Population Density
Figure 16 illustrates transmission and distribution losses and population density in some LAC in 2009. Population density affects in different ways LAC. With the highest population density, between the examined countries, Costa Rica has one of the lowest losses rate in the region and thus follows expected international experiences. Contrary to this, Nicaragua, with twofold population density than Chile, has experienced more than twofold losses.

![Figure 16. Transmission and Distribution Losses and Population Density in Latin America, 2009](source)

Figure 16. Transmission and Distribution Losses and Population Density in Latin America, 2009

3.2 Economic development
Economic development positively impacts losses in LAC (Figure 17). With the highest level of GNI per capita PPP, Chile shows the lowest loss indicator between the analyzed countries.

![Figure 17. Transmission and Distribution Losses and GNI per capita in Latin America, 2009](source)

Figure 17. Transmission and Distribution Losses and GNI per capita in Latin America, 2009

Note: GNI per capita based on purchasing power parity (PPP). PPP GNI is gross national income (GNI) converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GNI as a U.S. dollar has in the United States. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. Data are in current international dollars.
3.3 Public/Private Sector Participation

The involvement of the private sector in generation, transmission and distribution has improved the situation somewhat, but there are still differences between the examined countries (Figure 18). Even if private participation is high in Nicaragua’s distribution sector, losses still remain high. However, its losses have decreased during last years (Figure 11). Chile and Argentina are good successful examples of private sector’s efforts to reduce losses (Figures 7, 8 and 18).

![Diagram showing Transmission and Distribution Losses (%) in Latin America, 2009](image)


Figure 18. Transmission and Distribution Losses and Private Sector Participation in Latin America, 2009

4. Economic Impact of Non-technical Losses in Latin America

In this section, we discuss the following five issues dealing with economic impact of losses in Latin America:

1. Utilities’ financial sustainability.
2. Allocation of electricity loss costs.
3. Impact of losses on electricity demand and economic grid expansion.
4. Losses and access to energy.
5. Measures to reduce losses and improve revenues for utilities.
4.1 Utilities’ financial sustainability

As mentioned before, transmitting and distributing electrical power through a network inevitably results in losses of energy. They represent for utilities losses in revenues. In order to recover all costs involved in the supply of electricity and to fill the utility viability gap, costs of losses should be covered by paying users or by Governments via targeted output-based subsidies.

4.2 Allocation of electricity loss costs

Since one or more generators must produce this lost energy and since these generators expect to be paid for all the energy they produce, a mechanism must be devised to take losses and their cost into account in electricity markets.

Because losses are not a linear function of the flows in the transmission system, the losses caused by a transaction do not simply depend on the amount of power traded and the location of the two parties involved in the transaction (Kirschen D. and G. Strbac, 2004). They also depend on all the other transactions taking place in the network. Allocating the losses or their cost between all the market participants is thus a problem that does not have a rigorous solution. Nevertheless, this cost must be paid and shared fairly. A fair mechanism is one in which participants that contribute more to losses (e.g. remote generators and consumers) pay a larger share that the others. Conejo et al. (2002) discuss various methods that have been proposed to allocate the cost of losses on an approximately fair basis.

4.3 Impact of losses on electricity demand and economic grid expansion

On the demand side, losses reduction and improvement on energy efficiency would partially cover the expected demand rise without the necessity to increase the installed capacity (De Nigris M. and M. Coviello, 2012).

On the supply side, losses undermine the ability of the utility to finance new generation capacity. The problem is particularly pronounced in countries like some LAC with a vertically integrated monopoly, where a (mostly) state-owned company is responsible for generation, transmission, and distribution, with limited transparency into the overall system. But liberalized systems, where generation is split from distribution, are not immune to capacity challenges. In these instances, firms on the generation side often have reduced incentive to invest in capacity due to high credit risks associated with electricity offtakers (typically distribution companies that cannot collect the revenues they are due) (IFC, 2012).

4.4 Losses and access to energy

Even when access to the grid is available, customers in many developing countries like LAC are plagued by unreliable power. Where system inefficiencies and theft create significant losses, utilities are unable to cover their costs. The result is that companies struggle with solvency and are unable to provide high-quality service to existing customers, let alone deliver new connections. Hence, despite having “access,” it is not unusual for households and businesses to rely on expensive power from back-up generators to make up for poor utility service (IFC, 2012).

4.5 Measures to reduce losses and improve revenues for utilities

For Government, utilities and paying users, economic impact due to non-technical losses create incentives to put in place policies and actions to reduce losses. In LAC, some of these actions can be classified as follows:

Social
- Preventions of theft.
- Social contracts with communities to encourage legal connections.
Economic
- Management of payment risk.
- Special tariff regimes (based on time of use, pre-paid formulas, etc.).
- Flexible payment options.

Technical
- Improvement in commercial processes.
- Advanced metering systems as installation of electronic meters, prepaid meters, anti-damping connections and collective electronic meters.

The use of technological innovations such as smart grid will help in the future LAC reduce non-technical losses. A smart grid uses metering devices, telemetry and control software to optimize the power delivered, minimizing losses and power interruptions, as well as transmitting only the necessary amount. The US firm claims that South America in particular has a series of market conditions that make it more attractive for the development of smart grids than other emerging regions like Asia (BNA, 2011). These include higher per capita energy consumption and non-technical losses (thefts) than in Asia, as well as huge potential to distribute generation. According to ECLAC (2012), the regional countries with the best potential for developing smart grids are Brazil, Mexico, Uruguay, Chile and Panama.

5. Conclusions

Electricity losses are more significant in developing than developed countries. Differences can vary from 5 to 30%. From LAC that have been studied, Chile and Costa Rica show the lowest loss levels (about 10%), meanwhile losses in Nicaragua and Venezuela reach 25-30%.

Regarding key drivers analysis, population density affects losses in different ways LAC. Some countries like Costa Rica follow expected international experiences in the sense of more density, less losses. Others, like Nicaragua, follow different patterns. Economic development positively impacts losses in LAC. With the highest level of GNI per capita PPP, Chile shows the lowest loss indicator between the analyzed countries. The involvement of the private sector in generation, transmission and distribution has improved the situation somewhat, but there are still differences between the examined countries.

Non-technical losses in Latin America are estimated to 5 to 10% in average, with peaks as high as 20%. Its negative economic impact to electric companies’ financial sustainability, particularly public state-owned, should be covered by paying users or by Governments via subsidies. Many best practices in public state-owned and private companies to diminish non-technical losses are found in different LAC than can be used as references by other countries in the region. Smart grid appears to be in the near future one of the most innovative and effective practices that can be implemented in the region to reduce non-technical losses.

Finally, it could be interesting to analyze other key drivers of losses such as age of the grid, investments in transmission and distribution systems, among others.

References


