Reducing T&D Losses Allows Faster Retirement of Fossil Plants

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Contact: Jacobson@stanford.edu; Twitter @mzjacobson

Summary

- 54 Percent of Countries Have Transmission & Distribution (T&D) Losses of 10 to 72 Percent

- Every One Percentage Point Decrease in T&D Losses Can Allow 1.6 to 5.4 Percent of Fossil Plants to Retire For Respective Loss Rates of 2 to 72 Percent

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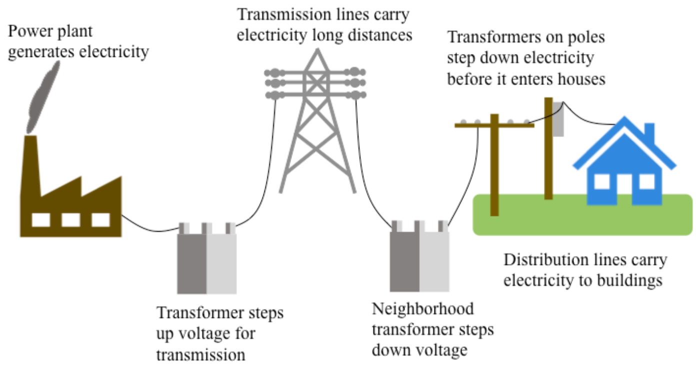
6.6.6. Factors Reducing Wind Turbine Gross Annual Energy Output

Some of a wind turbine's gross annual energy output, determined from Equation 6.24, is lost due to four factors: transmission and distribution losses, downtime, losses, curtailment losses, and array losses.

6.6.6.1. Transmission and Distribution Losses

Figure 6.10 illustrates the AC **transmission and distribution (T&D) system**. AC electricity flows along a transmission line from an electric power generating facility to a step-up transformer station. The station boosts the voltage to produce high voltage AC (HVAC) electricity in order to reduce long-distance AC transmission losses (Example 4.8). Along the HVAC line, AC electricity may or may not be converted to DC electricity for extra-long-distance HVDC transmission (not shown in Figure 6.10). At the end of the HVDC line, the DC electricity is converted back to HVAC electricity. The HVAC electricity is then transmitted to a step-down transformer station in a neighborhood, where the voltage is decreased, and the electricity is sent to local distribution lines. Electricity then goes to a transformer near buildings, where the AC voltage is dropped further for use in the buildings.

Figure 6.10. Diagram of transmission and distribution system. See text for a description.



Losses along transmission and distribution (T&D) lines arise due to five factors. First, resistance along transmission and distribution lines converts some electricity to heat. Second, losses arise from step-up and step-down transformers to convert low voltage to high voltage AC (HVAC) electricity and back again. Losses similarly arise in local transformers, which reduce voltage further for electricity use in buildings, at the end of distribution lines. Third, losses occur in equipment converting HVAC electricity to HVDC electricity and back again. Fourth, losses arise from downed power lines. Fifth, in countries with transmission and distribution loss rates above 15 percent (e.g., Table 6.3), electricity theft from power lines is a major source of loss (Sadovskaia et al., 2019).

Of all transmission and distribution losses in the current energy system in countries without theft of power, about 16 to 33 percent are short and long distance transmission losses from the electricity generator station to the step-down transformer substation, 32 to 40 percent are distribution losses between the step-down substation and the end user, and 27 to 52 percent are transformer losses (IEC, 2007).

When HVAC electricity is converted to HVDC electricity for extra-long-distance transmission (beyond 600 km), transmission losses are reduced compared with HVAC transmission (Section 4.7). For example, the overall loss of electricity along an 800 kV HVDC line ranges from 2.5 to 4 percent per 1,000 km compared with twice that for an HVAC line (ABB, 2004, 2005). However, a portion of the benefit of long-distance HVDC transmission is offset by losses arising from the HVAC-to-HVDC-to-HVAC conversion process. Such converter station losses are about 0.6 percent of energy transmitted (ABB, 2004).

Table 6.3 summarizes average transmission and distribution losses by country of the world in 2014. The losses range from 2 percent in Singapore to 72.5 percent in Togo. Fifty-four percent of the countries have T&D losses 10 percent or higher. Losses in some large countries and regions are as follows: China (4 percent), the United States (5.9), the European Union (6.4), the Russian Federation (10), Brazil (15.8), and India (19.4). The world average is 8.3 percent (World Bank). An independent analysis suggests that total transmission and distribution losses in the U.S. between 2012 and 2016 were similarly about 5 percent of electricity generation (EIA, 2018e).

Table 6.3. Percent of electricity production lost by transmission and distribution losses by country in 2014.

Country	Loss	Country	Loss	Country	Loss	Country	Loss
Singapore	2.0	Paraguay	6.6	Peru	11.0	Nigeria	16.1
Trinidad/Tobago	2.3	Switzerland	6.7	Egypt	11.2	Zimbabwe	16.4
Slovak Republic	2.5	Kazakhstan	6.7	Angola	11.3	Tajikistan	17.0
Iceland	2.7	Estonia	6.8	El Salvador	11.3	Algeria	17.1
Israel	2.9	Saudi Arabia	6.8	Bangladesh	11.4	Pakistan	17.4
Gibraltar	3.0	Italy	7.0	Sri Lanka	11.4	Montenegro	17.5
South Korea	3.3	U.A. Emirates	7.2	Dominican Rep.	11.6	Kenya	17.6
Germany	3.9	Ireland	7.9	Kuwait	11.7	Tanzania	17.7

Bahrain	3.9	Bosnia & Herz.	8.2	Armenia	12.0	Ethiopia	18.5
Cyprus	4.0	Greece	8.2	Hungary	12.4	India	19.4
Finland	4.1	United Kingdom	8.3	Turkmenistan	12.5	Myanmar	20.5
Japan	4.4	South Africa	8.4	Hong Kong	12.5	Nicaragua	20.8
Czech Republic	4.5	Bulgaria	8.6	Iran	12.6	Congo, DR	21.5
Malta	4.7	Suriname	8.7	Senegal	12.8	Moldova	21.5
Netherlands	4.8	Uzbekistan	8.8	Ecuador	12.9	Lithuania	22.0
Sweden	4.8	Canada	8.9	Croatia	13.1	Ghana	22.6
Australia	4.8	Latvia	9.0	Eritrea	13.5	Cambodia	23.4
Slovenia	4.8	Belarus	9.2	Azerbaijan	13.6	Gabon	23.4
Austria	5.3	Bolivia	9.2	Mexico	13.7	Albania	23.7
Belgium	5.4	Vietnam	9.2	Sudan	14.3	Kyrgyz Rep.	23.7
China	5.5	Indonesia	9.4	Panama	14.3	Yemen	25.8
South Sudan	5.7	Philippines	9.4	Ivory Coast	14.3	Jamaica	26.7
Georgia	5.8	Guatemala	9.5	Argentina	14.3	Niger	26.8
Malaysia	5.8	Spain	9.6	Morocco	14.7	Nepal	32.2
United States	5.9	Uruguay	9.6	Mozambique	14.7	Honduras	34.9
Qatar	6.1	Cameroon	9.8	Mongolia	14.8	Venezuela	36.0
Norway	6.1	Portugal	10.0	Turkey	14.8	Namibia	36.2
Thailand	6.1	Russian Fed.	10.0	Tunisia	14.9	Congo, Rep.	44.5
Denmark	6.1	Lebanon	10.5	Zambia	15.0	Iraq	50.6
Mauritius	6.2	Colombia	10.7	Kosovo	15.0	Haiti	60.1
Luxembourg	6.3	Jordan	10.7	Cuba	15.3	Libya	69.7
France	6.4	Ukraine	10.8	Syria	15.4	Togo	72.5
Brunei Darussalam	6.4	Botswana	10.8	Serbia	15.4		
Poland	6.5	Costa Rica	10.8	Brazil	15.8		
New Zealand	6.5	Oman	10.9	North Korea	15.8	European Union	6.4
Chile	6.5	Romania	10.9	Curacao	16.0	**World**	**8.3**

From World Bank (2018)

Table 6.3 indicates that a lot of room exists for reducing electricity losses in many countries of the world, particularly countries with T&D losses exceeding 10 percent, including Brazil and India. Reducing losses will result in substantial, low-cost benefits. Equation 6.30, derived here mathematically, quantifies some of the benefits of reducing T&D losses. It gives the percent reduction in electric power generation (ΔG_{elec}) needed, compared with the original generation, if T&D losses, originally L_{TD} percent, are reduced by ΔL_{TD} percentage points:

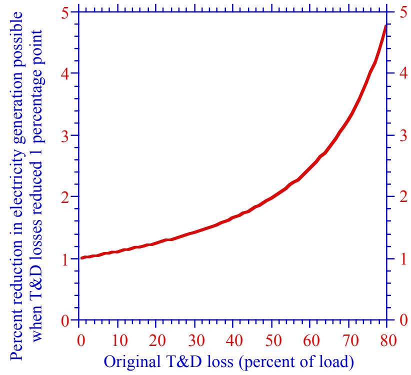
$$\Delta G_{elec} = \frac{100 \times \Delta L_{TD}}{100 - L_{TD} + \Delta L_{TD}} \tag{6.30}$$

Equation 6.30 indicates that, if a country's current T&D loss rate is 10 percent, reducing the loss rate by 1 percentage point to 9 percent will reduce electricity generation requirements in the country by 1.1 percent. If the current loss rate is 20 percent, a 1 percentage point reduction will reduce generation requirements by 1.23 percent. If the loss rate is 72.5 percent, as in the case of Togo, simply reducing the loss rate to 71.5 percent will reduce the generation requirement by 3.5 percent (Example 6.9). Figure 6.11 shows a plot of Equation 6.30 for T&D loss rates that cover the range of all countries in Table 6.3. It illustrates that benefits of reducing T&D losses occur all the way down to a current loss rate of 1 percent.

Example 6.9. Reducing electricity generation requirements by reducing transmission and distribution losses.
Calculate the reduction in electricity generation that is possible, without reducing end-use electricity availability in Togo if T&D losses are reduced by ΔL_{TD} = 1 percentage point from their 2014 value of L_{TD} = 72.5 percent.

Solution:
From Equation 6.30, $\Delta G_{elec} = 100 \times 1 / (100 - 72.5 + 1) = 3.5$ percent.

Figure 6.11. Percent reduction in electricity generation from power plants that is possible if transmission and distribution losses are reduced by 1 percentage point below the original T&D loss. Thus, for example, if the original T&D loss is 50 percent and reduced by 1 percentage point to 49 percent, 1.96 percent less electricity generation is needed from power plants. The numbers in the figure are obtained from Equation 6.30.



Reducing the loss rate by 1 percentage point allows even more fossil fuel generation to retire than is indicated by Equation 6.30 and Figure 6.11. The reason is that fossil fuels usually do not supply 100 percent of electricity in a country. As such, if all electricity reductions that result from reducing T&D losses are obtained by shutting fossil fuel plants, a higher percent of fossil fuel plants will be shut than Equation 6.30 indicates. Example 6.10 shows, for example, that **a country with 20 percent T&D losses and 60 percent of its electricity from fossil fuels can reduce overall electricity production by 1.23 percent and fossil fuel production requirements by 2.05 percent simply by reducing T&D losses 1 percentage point.**

Example 6.10. Reducing fossil fuel generation requirements when reducing T&D losses.
Calculate the reduction in fossil fuel electricity generation that is possible upon a 1 percentage point reduction in T&D losses for a country that currently has 20 percent T&D losses and provides 60 percent of its electricity from fossil fuels.

Solution:
From equation 6.30, $\Delta G_{elec} = 100 \times 1 / (100 - 20 + 1) = 1.23$ percent, which is the percent reduction in electricity generation that can be obtained in the country with a 1 percentage point reduction in T&D losses. Since fossil fuels produce 60 percent of the electricity, this means that 1.23 percent / 0.6 = 2.05 percent of fossil fuel generation can be reduced. In other words, for every one percentage point of T&D loss reductions, the country can eliminate over 2 percent of its fossil fuel electricity generation fleet.

In 2019, about 65 percent of all electricity worldwide was produced from fossil fuels. If the world average T&D loss were reduced from 8.3 to 7.3 percent, world electricity generation could be reduced by 1.08 percent and fossil fuel generation could be reduced by 1.66 percent. The range in fossil fuel reductions possible for individual countries under the same assumption is 1.55 to 5.4 percent.

Replacing T&D equipment costs only a fraction of the cost savings of reducing electricity generation. Coal and gas plants spend money on mining, transporting, and processing fossil fuels and on the rest of their operations. They charge consumers for the resulting electricity. If the electricity is wasted as heat or theft in the T&D system, consumers are paying for electricity that no one uses. Only a portion of wasted energy costs are needed to upgrade the T&D system, and the upgrades will last up to 70 years for some of the T&D components.

By eliminating extraneous coal and gas plants, a country also reduces health and climate costs due to unnecessary pollution that is emitted to produce electricity that is not used because it is wasted along the

T&D system. Eliminating extraneous fossil plants further reduces the devastation to land and water due to unnecessary mining for fossil fuels used in the plants.

Finally, in a 100 percent WWS world, a portion of new electricity generation, including from offshore wind, tidal, wave, and floating solar power will be offshore. Offshore renewables often require short transmission distances to load centers because most people in the world live along the coasts, and most offshore resources will be sited 0 to 200 km offshore. As such, the growth of offshore renewables should increase the efficiency of the T&D system.

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