Transmission and Distribution Benefits of Pole Mounted PV Power Generation Systems

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Introduction

Distributed Generation (DG) systems are small-scale power generation systems ranging from a few hundred watts to mega watts, which are being used to provide an alternative or an enhancement to traditional electric power generation systems. DG systems cover a wide array of technologies including photovoltaic solar arrays, wind turbines, micro-turbines, as well as fuel cells. They are typically owned and operated by utilities as well as customers themselves to reduce energy costs, boost on-site power reliability, and improve power quality. DG systems derived from renewable energy sources are rapidly becoming an integral part of utility grids throughout the world. This has been driven by a continuous rise in demand for electricity, skyrocketing oil prices, aging grid infrastructure, and new mandates to reduce CO_2 emission.

DG power systems have a number of benefits including reducing the amount of energy lost in transmitting electricity since the power is being generated near load sites. This also reduces the size and number of power lines that must be constructed and maintained. In addition, DG systems can offer many potential benefits to the electric system if integrated into utilities' planning and operations processes. On a local basis, utilities can:

- Utilize DG systems to supplement a distribution system's ability to supply sufficient power during periods of peak demand
- Provide ancillary services such as reactive power and voltage support
- Improve power quality

Using Distributed Generation to meet these local system needs can enhance overall electric system reliability.

Petra Solar Pole Mounted SunWave™ AC PV Modules

Petra Solar's pole mounted SunWave™ AC PV generation system takes the granularity of DG systems one step further as it "evenly" distributes the generated power throughout the electric distribution network thus further reducing distribution losses and bringing power even closer to where it is being used.

[1] Niagara Mohawk Paper Corporation.

Fig. 1
Petra Solar's "highly distributed" SunWave™ pole mounted PV power generation system

Transmission & Distribution System
The transmission and distribution (T&D) system includes everything between the generation plant and an end-use site. Some of the energy supplied by the generator is lost due to the resistance of the wires and equipment that the electricity passes through; the lost energy is converted to heat.

T&D losses are mainly due to transmitting electricity over long distances and are inherent in all devices that the electric current passes through. As such, these losses are caused by transmission line conductor (resistive) losses and distribution transformer conductor and core losses. Over a T&D network the losses can be broken down into transmission, sub-transmission, primary distribution, and secondary distribution losses as shown in Fig. 2.

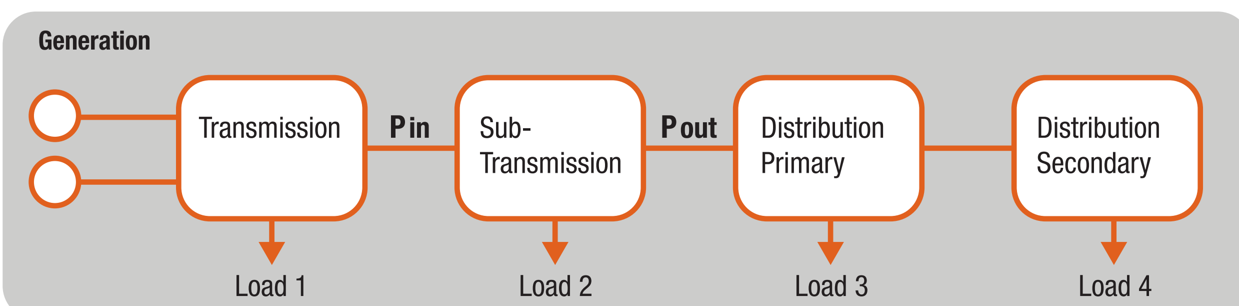

Fig. 2
T&D Loss Breakdown

The Energy Expansion Factor (EEF) is typically used to determine total energy obligation when the actual load is known. As such, the EEF combines the total actual usage as well as the T&D losses and is given by:

$$EEF = \frac{P_{in}}{P_0} = \frac{P_0 + P_{loss}}{P_0} = 1 + \frac{P_{loss}}{P_0}$$

Typical energy expansion factors for each level of the T&D network are given in Table 1 while cumulative factors are given in Table 2[1].

Table 1
System Level EEF

Level	EEF
Transmission	1.027
Sub-Transmission	1.026
Distribution Primary	1.042
Distribution Secondary	1.063

Table 2
Cumulative EEF*

Level	EEF
Transmission	1.027
Trans. + Sub-Trans.	1.053
Trans. + Sub-Trans. + Dist. Pri.	1.069
Trans. + Sub-Trans. + Dist. Pri. + Dist. Sec.	1.092

* Note that the cumulative EEF values are not strictly additive.

As shown in Table 2, the T&D cumulative losses are quite significant and can reach 9.2% at the secondary distribution circuit.

T&D losses in the U.S. are in the range of 6% to 9%. With net U.S. generation in 2008 being well over 4.1 billion megawatt hours (MWh), the T&D losses amounted to 245 million MWh, or 6.0% of net generation[2] (Fig. 3). Using the national average retail price of electricity for 2008 of ¢9.75/kWh, one can estimate these losses be close to $23.9 billion. Adding DG capacity will allow utilities to reduce these losses and allow for added transmission and distribution capacity to cope with demand growth.

In Ontario, the T&D losses were estimated at an average of 7.5% by the Ontario Clean Air Alliance[3]. During peak demand hours, the T&D losses are quite higher, reaching well over 20%[4].

Benefits of Distributed Generation: Reduced Line Losses

Opportunities to reduce the T&D losses exist throughout the various levels of the T&D system. DG installed on the secondary distribution system has the potential to eliminate up to 9% in T&D losses, reduce remote generation requirements and free up T&D capacity.

The Petra Solar "highly distributed" PV generation system is installed throughout the secondary distribution system of a utility grid. As such, the power generated by Petra Solar's distributed PV generation system will yield reduction in T&D losses as well as reduction in remote generation levels. To quantify these benefits, a simplified model will be used.

[2] Data from Energy Information Administration (EIA). http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html

[3] Ontario Clean Air Alliance (2009). Opening the Door to Clean Power in Toronto: Removing barriers to combined heat and power and distributed generation. Access at http://www.cleanairalliance.org/files/active/0/cesop-web.pdf

[4] "Ontario Missed Opportunities," Tom Casten, Energy Management, July/August 2008, pp. 14.

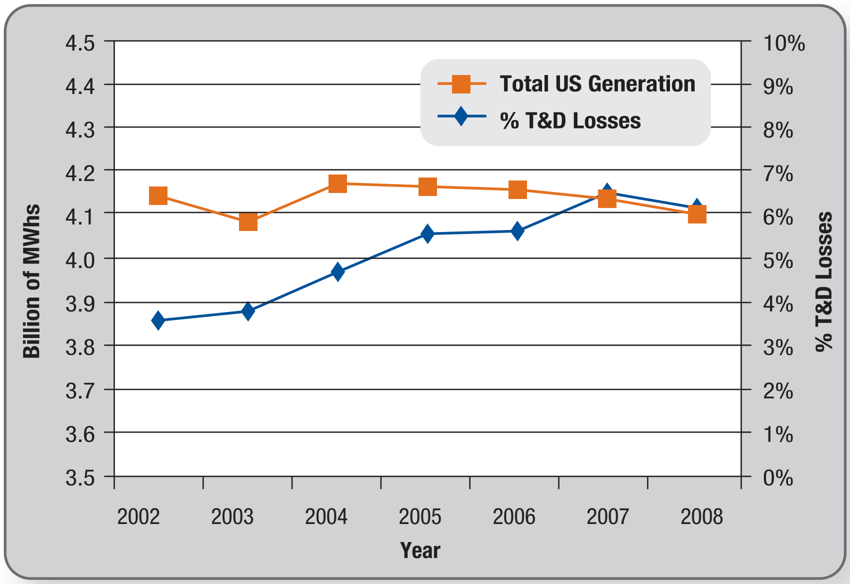

Fig. 3
U.S. Generation and T&D Losses, 2002 - 2008

With the SunWave™ systems, power is generated very close to the load, so one can assume that the majority of the T&D losses are essentially eliminated. As such, and assuming an average of 7.5% T&D losses (Ontario), for every MW of installed secondary circuit DG capacity, the remote power generation capacity is reduced by 1 MW, while the T&D losses are reduced by 7.5% minus the local distribution losses. Assuming local distribution losses of 1-2%, the total T&D savings will amount to 5.5%-6%, or close to 60 kW for every 1 MW of installed secondary circuit DG capacity.

Since solar PV systems will only generate power when the sun is out, one needs to take into account that actual power generated is a percentage of the peak capacity installed. The following is a simplified estimate of the T&D loss savings by a highly distributed PV generation system.

- By averaging the generated PV power over a whole day for Ontario, and assuming 4.17 hours of average annual sun-hours per day, the average continuous generation capacity for every 1 MW of peak PV will be 174 kW (1MW x 4.17h/24h).
- With line losses estimated at ~1-2%, total average power will be 171 kW.
- As such, the remote generation capacity will be reduced by 171 kW.
- Since the T&D losses are estimated at 7.5%, the resultant reduction in T&D losses will be 12.83 kW for every MW of peak PV installed or 112 MWhs per year.
- Using an average retail electricity price of $0.09/kWh, these savings amount to $10,115 per year or $202,303 per MW over the PV system lifetime (20 years) or approximately 4% of the installed cost.

Hence, for every 1MW of installed distributed PV capacity, remote power generation requirements will be lower by ~171 kW. This will yield approximately $10,115 of annual T&D loss savings or $202,303 over 20 years.

Benefits of Distributed Generation: Reduced Peak Power Requirements

Another aspect of distributed PV generation is the reduction in peak power demand requirements. The peak installed capacity of PV is typically dispatched during peak demand hours, thus reducing the need to install, maintain and run costly standby peak generation systems or "peakers."

Figure 4 shows Ontario's electricity load duration curve for 2006[5]. As shown in the left side of the curve, Ontario's peak demand in 2006 was 27,005 megawatts (MW) while the minimum electricity demand was approximately 12,000 MW. Note that the peak demand for electricity in the year exceeded 23,389 MW for only 88 hours or just 1% of the total 8,760 hours in a year. This peak demand lasted for less than 1% of the year, and occurred during the hottest days of the year. Meeting this 1% peak demand is extremely costly since the electricity generation and transmission infrastructure required to meet this fleeting demand is used for 1% of the year or less. According to the Ontario Power Authority (OPA), the cost of meeting the top 1% of demand with new electricity infrastructure is $1.64 per kWh.

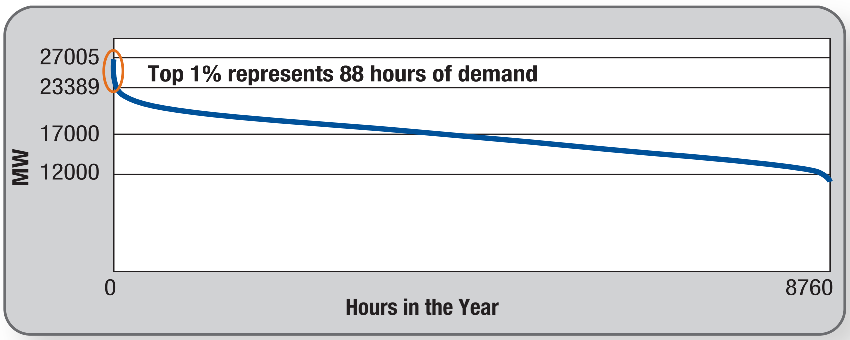

Fig. 4
Ontario's Electricity Demand in 2006

Petra Solar's distributed PV generation system will help offset this demand since this demand occurs during the hottest days where the sun is definitely out. The simple model below will estimate the savings associated with reduced remote peak generation demand.

- Every 1MW of installed peak PV capacity will result in 850kW of reduced remote peak power generation (using PVWatts model).
- Using the $1.64/kWhr figure quoted by the OPA, every 1MW of peak installed PV will reduce remote peak generation demand by 850 kWhs per hour resulting in $1,394 per hour of savings.
- Since top peak lasts 88 hours per year, the total cost savings per year will amount to $122,672 per year.
- As such, the overall peak savings over the system life time will amount $2.45 million for every MW of installed PV capacity.

Hence, for every 1MW of installed distributed PV capacity, peak power generation requirements will be reduced by 850 kWhs per hour resulting in annual savings of up to $122,672 per year or $2.45 million over the system lifetime.

[5]"Reducing Peak Demand" Ontario Clean Alr Alliance, www.cleanairalliance.org

Conclusions

The SunWave™ AC PV module offers a truly distributed renewable power generation system and can realize significant benefits to utilities. These include reduced transmission and distribution losses and reduced peak power generation capacity. The savings associated with these benefits are considerable and can add up to a significant portion of the initial investment.

References

1 Energy Information Administration (EIA): http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html

2 Ontario Clean Air Alliance (2009). Opening the Door to Clean Power in Toronto: Removing barriers to combined heat and power and distributed generation: http://www.cleanairalliance.org/files/active/0/cesop-web.pdf

3 "Ontario Missed Opportunities," Tom Casten, Energy Management, July/August 2008, pp. 14.

4 "Reducing Peak Demand," Ontario Clean Air Alliance, www.cleanairalliance.org

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