FREQUENTLY ASKED QUESTIONS AND ANSWERS

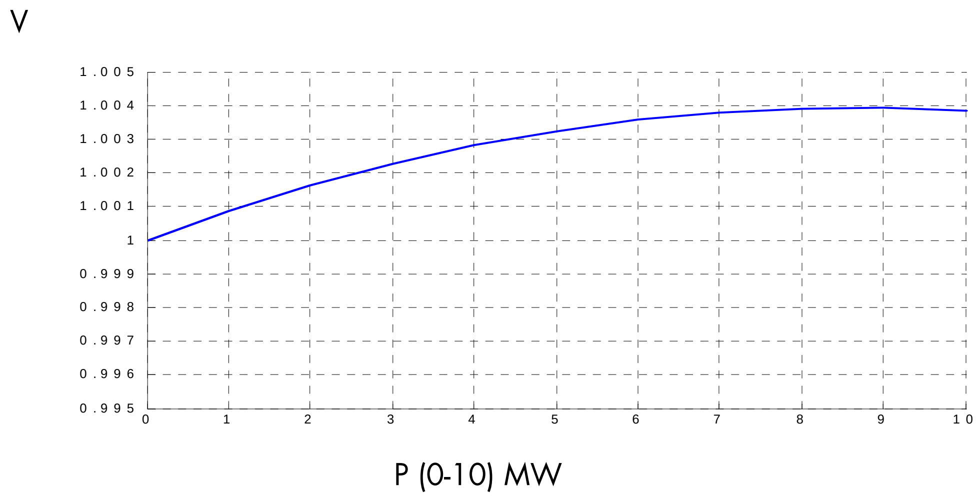
Technical Interconnection Requirement (TIR) Addendum: Webinar #1 and #2
September 9 and September 24, 2010

1. How does operation with a fixed power factor control voltage fluctuations of DGs with variable energy sources like wind and solar?

Published technical literature, as well as our findings, confirms that constant power factor control can limit voltage fluctuation.

Hydro One assigns a power factor at the Point of Common Coupling (PCC) according to specific system conditions to maintain feeder voltages within acceptable levels, as well as to limit voltage fluctuation.

Consider the following illustrative example: A 10 MW DG is connected 15 km away from a station. The overall feeder X/R ratio from the station to the PCC is 2.5.

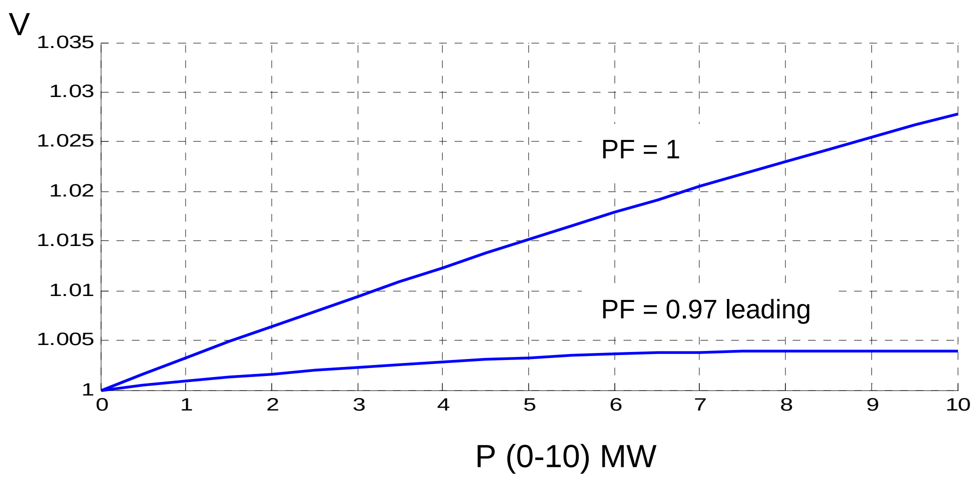


The voltage-power profile at the PCC is drawn assuming a constant power factor of 0.97.

The voltage-power profile defines how much the PCC voltage will change as compared to the pre-connection voltage, if the generator output varies from 0 to rated power.

In the example, the pre-connection voltage is normalized to 1.0 p.u. as indicated by the voltage when P is equal to 0. The maximum voltage is 1.004 p.u. for the entire range of generator output. Therefore, one can conclude from the voltage-power profile that the voltage fluctuation due to DG power variation will not exceed 0.4% under this operating condition. Therefore voltage fluctuation is limited using constant power factor control.

As a comparison, the voltage – power profile with unity power factor is also drawn in the following graph. It shows that voltage fluctuation becomes worse when power varies for unity power factor.



2. How does Hydro One define short-term voltage fluctuation?

In the context of the voltage performance criteria, short term voltage fluctuation refers to the voltage fluctuation caused by DG power variations, as opposed to that caused by slow load variations. The time-frame is in the order of minutes and the following output power fluctuation of an individual DG is currently assumed to be:

- for wind farms 30% of DG capacity
- for solar farms 60% of DG capacity

3. What impact will the changes proposed in this Addendum have on station capacity and the physical location of DGs?

From the point of view of voltage performance, the capacity limits depend on how well individual DGs meet the voltage performance criteria. How well an individual DG meets the performance criteria is impacted by the relative size and distance from the supply station. The relative distance depends on multiple factors, such as feeder X/R ratio, feeder voltage level, type and size of the DG, distance from the supply station and the station short circuit strength. These criteria basically try to limit the reactive power consumption attributed to individual DGs to limit voltage fluctuation and to prevent post-contingency voltage violation.

The more reactive power individual DGs absorb under light-load conditions, the less DG capacity a station can accommodate. (Refer to Webinar #2 presentation slides, interrelationship between feeder and station level criteria). As a rule of thumb, the total reactive power consumption attributed to DGs on a feeder should not exceed one-third of the DG real power output under light-load conditions in order to avoid severely limiting the station DG capacity.

In a pessimistic scenario, if all DGs just barely meet the rule of thumb, a station may just be able to accommodate DGs up to 12% of the station short-circuit MVA (from the view point of voltage regulation).

In an optimistic scenario, if all DGs are very close to the station and are able to maintain PCC power factor at unity, there is practically no limitation from the view point of voltage regulation.

Notes:

- There are other factors such as short-circuit and transformer ratings that impose other restrictions.
- A change in project location can be an acceptable approach to mitigating voltage performance criteria violations, as long as all other connection requirements are met.

4. What impact will the changes proposed in this Addendum have on connection costs?

The incremental changes to the TIR proposed in this Addendum do not affect costs to generators that meet all TIR requirements. Those projects affected by power-distance limitations may or may not see an impact, depending on the specific details of a given connection.

5. What methodology could a generator use to assess whether or not the proposed voltage criteria would be met, given the project location and connecting feeder?

Hydro One uses a series of direct and indirect tests to determine if a DG connection will meet all TIR requirements, including voltage performance criteria. These tests require feeder, station and embedded DG information normally not available to proponents. If there are any concerns about whether any specific application will result in voltage performance issues, proponents are encouraged to contact Hydro One to arrange for a pre-FIT consultation, where Hydro One consultants can take a more detailed look at the application and suggest possible ways to address voltage performance issues, if any.

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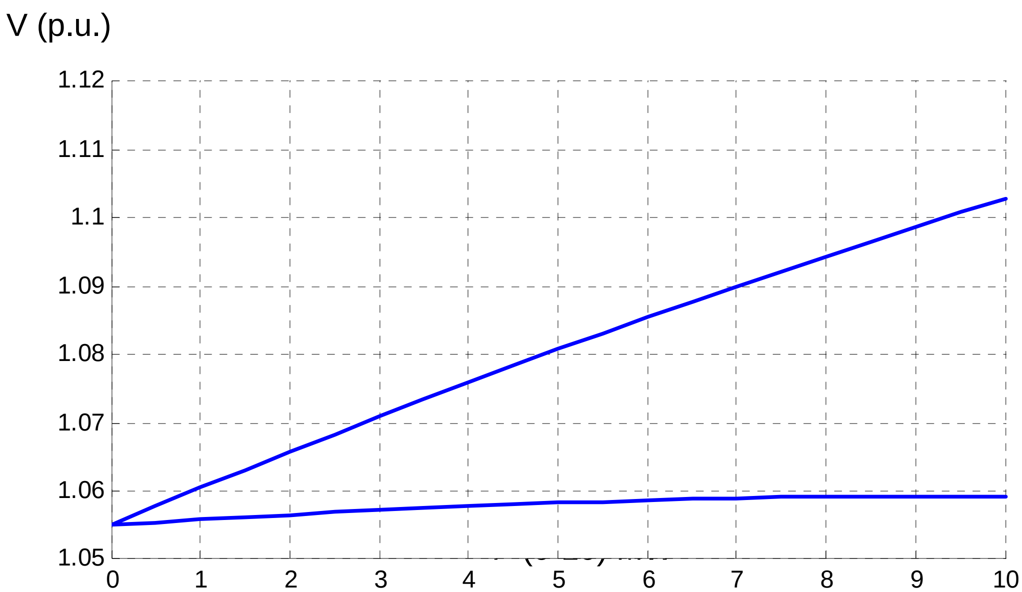
6. What MW size does Hydro One consider to be the lower limit of a large DG? How far is "far away" or "close" and what are these distances?

The Distribution System Code defines a large DG as greater than10 MW. However, in terms of the voltage performance criteria discussed in this TIR Addendum, whether a DG is too large or too far away depends on multiple factors, such as feeder X/R ratio, station strength, feeder loading condition, etc. Therefore the maximum DG size or distance is not a fixed number.

For example, consider a 10 MW DG connected 15 km away from a station, operating with PCC power factor of 0.97 leading. In order to illustrate the impact of X/R on the voltage profile, two voltage – power profiles are drawn in the following graph, one assuming feeder X/R = 2.5, and the other assuming feeder X/R =1. It is apparent that the feeder with X/R=1 will result in over-voltages, therefore the DG can be considered to be either electrically far away or "too large".



Some additional examples are provided below showing the impact of different parameters on voltage performance and hence acceptance of the DG.

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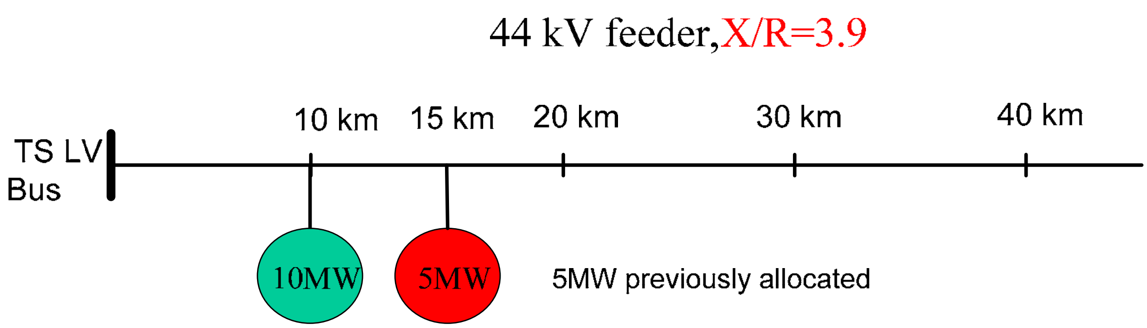
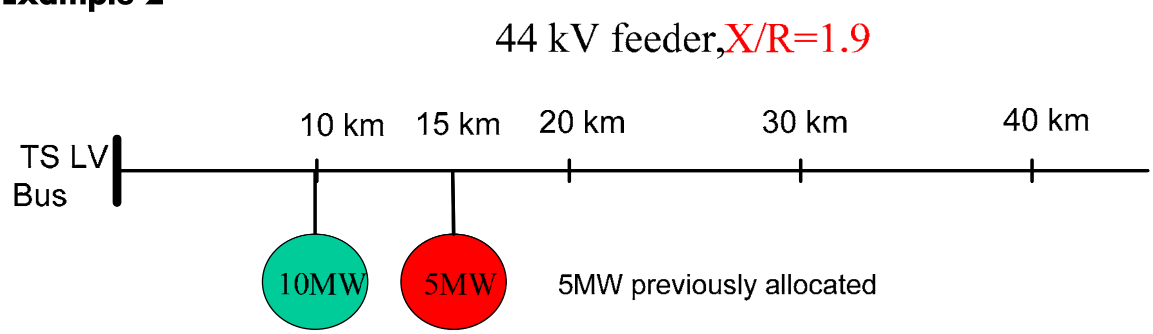
Additional Examples
Feeder X/R ratio influences a projects ability to connect

Example 1



- Application for 10 MW, 10km from the station bus is to be assessed
- Result: Connection is **acceptable**, due to high X/R ratio

Example 2



- Application for 10 MW, 10km from the station bus is to be assessed
- Result: Connection is **unacceptable,** due to low X/R ratio

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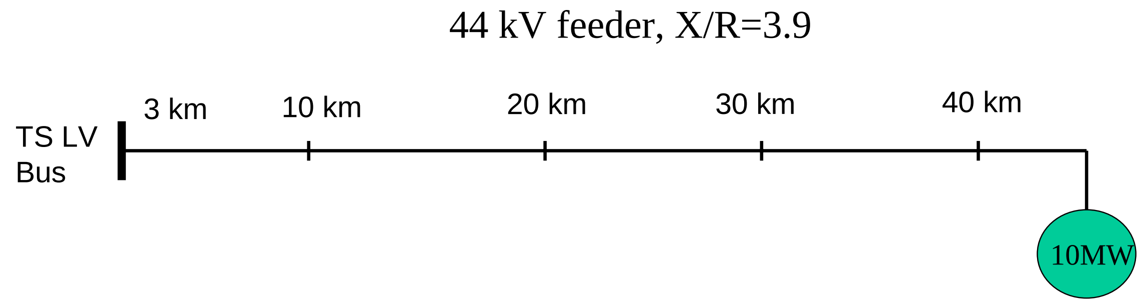
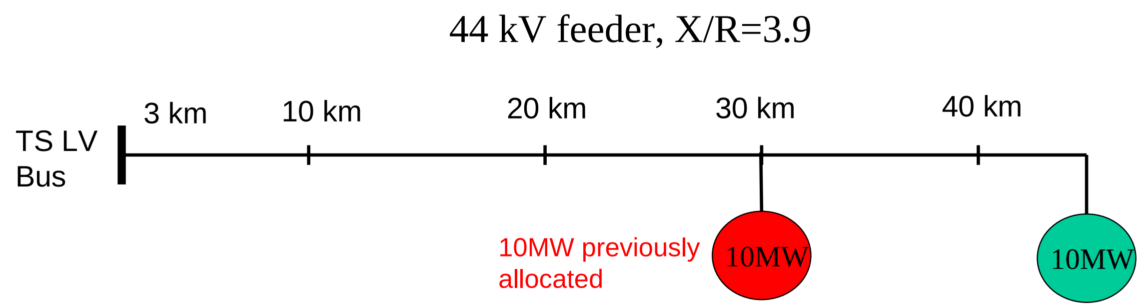
Impact of existing (or previously-allocated) DGs on an additional DG connection

Example 1



- 0 MW of previously allocated capacity
- Application for 10 MW, 45 km from the station bus is to be assessed
- Result: Connection is **acceptable,** due to no previously allocated capacity

Example 2



- Application for 10 MW, 45 km from the station bus is to be assessed
- Result: Connection is **unacceptable,** due to previously allocated capacity

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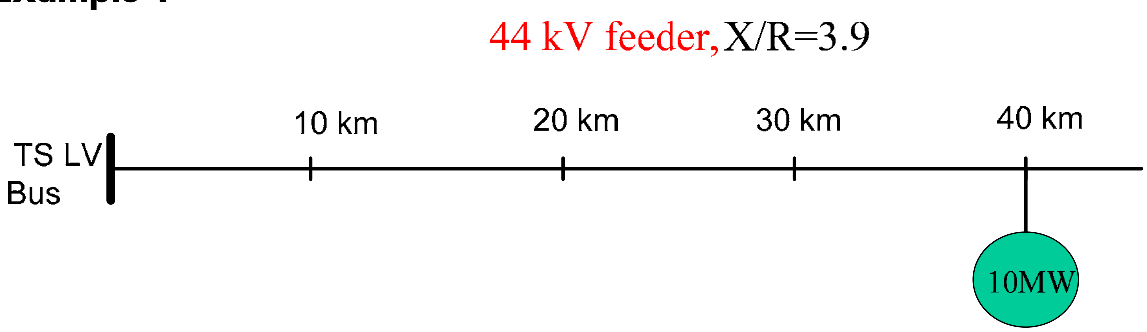
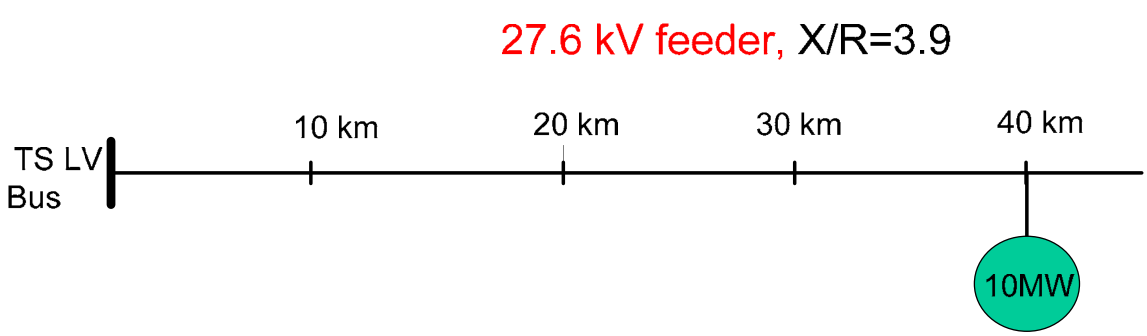
Impact of feeder voltage level on the ability of a DG to connect?

Example 1



- Application for 10 MW, 40 km from the station bus is to be assessed
- Result: Connection is **acceptable**, due to 44 kV connection

Example 2



- Application for 10 MW, 40 km from the station bus is to be assessed
- Result: Connection is **unacceptable,** due to 27.6 kV connection.