Distributed Generation
Technical Interconnection Requirements

Addendum

Distribution Voltage Performance Criteria and Requirements

Follow up Webinar
September 2010

Audio Dial-in:
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Presentation Overview

1. Introduction
2. Criteria Overview
   - Feeder level performance criteria
   - Station level performance criteria
3. Interrelationship between feeder and station level voltage performance criteria
4. Answers/Comments to Questions from First Webinar
5. Questions

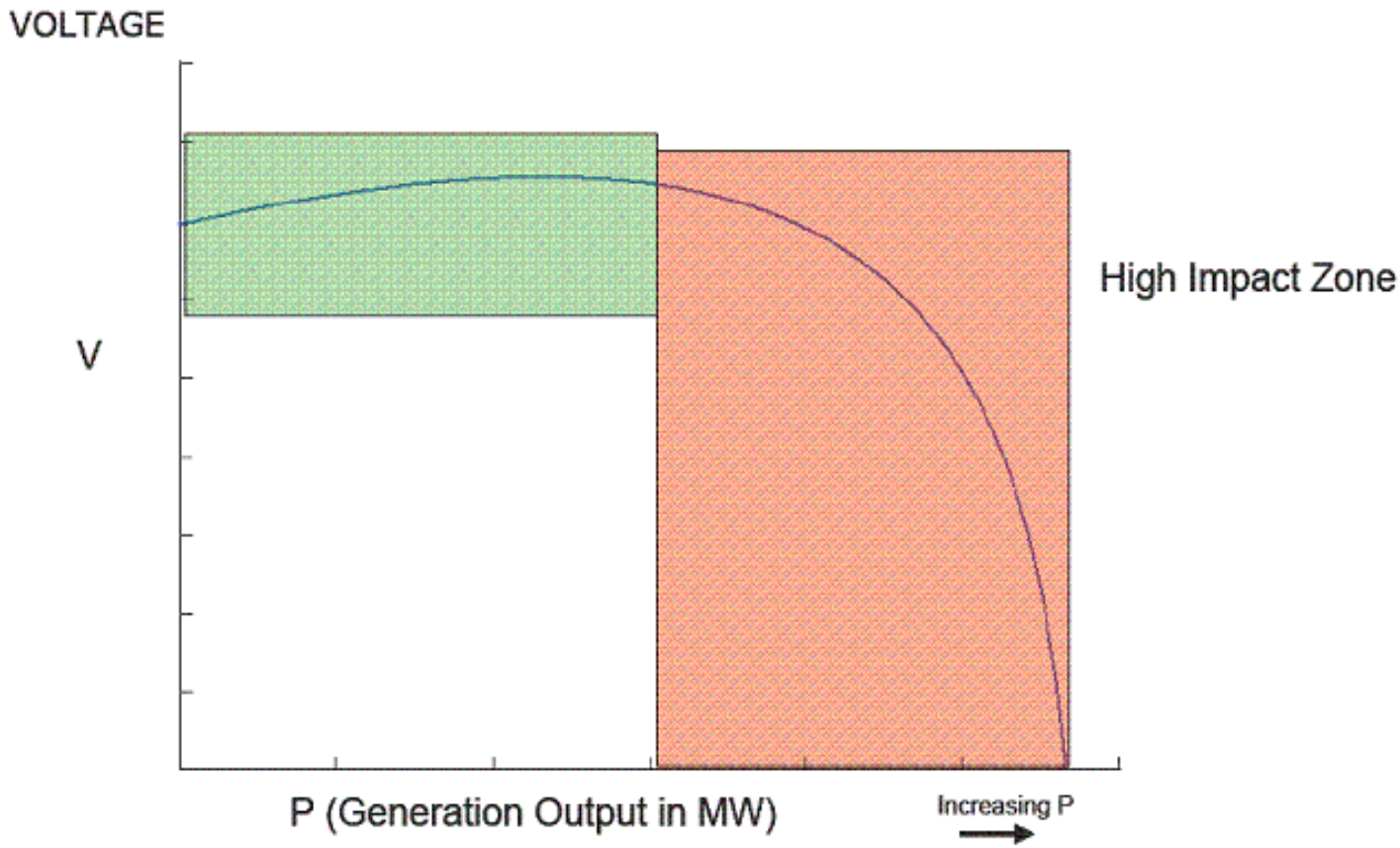
Introduction

- The first webinar on the Technical Interconnection Requirement Addendum presented on September 9 reviewed:
  - New voltage requirements and criteria
  - Questions and comments on the proposed criteria
- Today's follow up webinar discusses:
  - Criteria and responses to frequently asked questions
  - Presents illustrative examples

Introduction *(cont'd)*

- Based on experience with the connection of Distributed Generators (DGs) on long feeders, Hydro One became aware of numerous voltage performance issues
- Substantiated by field measurements
- Traditional limits (400A rule) proved insufficient
- New identified parameters and requirements: distance from PCC to the station bus, feeder X/R ratio, supply station strength and power output

Experience with Long Feeders Voltage-Power Profile



Criteria Overview

The basis of other performance criteria

- DGs shall not actively regulate their Point of Common Coupling (PCC) voltages
- At a time when Hydro One distribution system infrastructure can not support DG active voltage control, this criterion enables Hydro One to
  - manage reactive power flow, therefore to manage both pre- and post-contingency voltages
  - to limit short-term voltage fluctuation

Criteria Overview

Feeder level performance criteria

- PCC voltage shall be maintained within 0.94 ~1.06 p.u. and shall not be lower than pre-connection voltage

- At the feeder level, DGs shall not contribute to short-term voltage fluctuation anywhere on the feeder by more than 1%

Criteria Overview

Feeder level performance criteria *(cont'd)*

Comments

- The feeder level performance criteria will
  - ensure feeder voltages are within CSA limits
  - avoid customer complaints due to excessive voltage fluctuations
  - prevent excessive operation of voltage regulating facilities
- Feeder level performance criteria constrain the DG capacity of a feeder - how much generation can be connected at a given location from the view point of voltage performance

Criteria Overview

Station level performance criteria

- At the station level, all DGs connected to the TS/DS shall not collectively contribute to short term voltage fluctuation at the station LV bus by more than 1%

- Tripping of all DGs connected to the station shall not cause abrupt voltage change to result in a voltage above 110% of nominal bus voltage, or less than 90% of nominal bus voltage, after a single contingency and before the station Under Load Tap Changer (ULTC)/feeder Voltage Regulator (VR) operates

Criteria Overview

Station level performance criteria *(cont'd)*

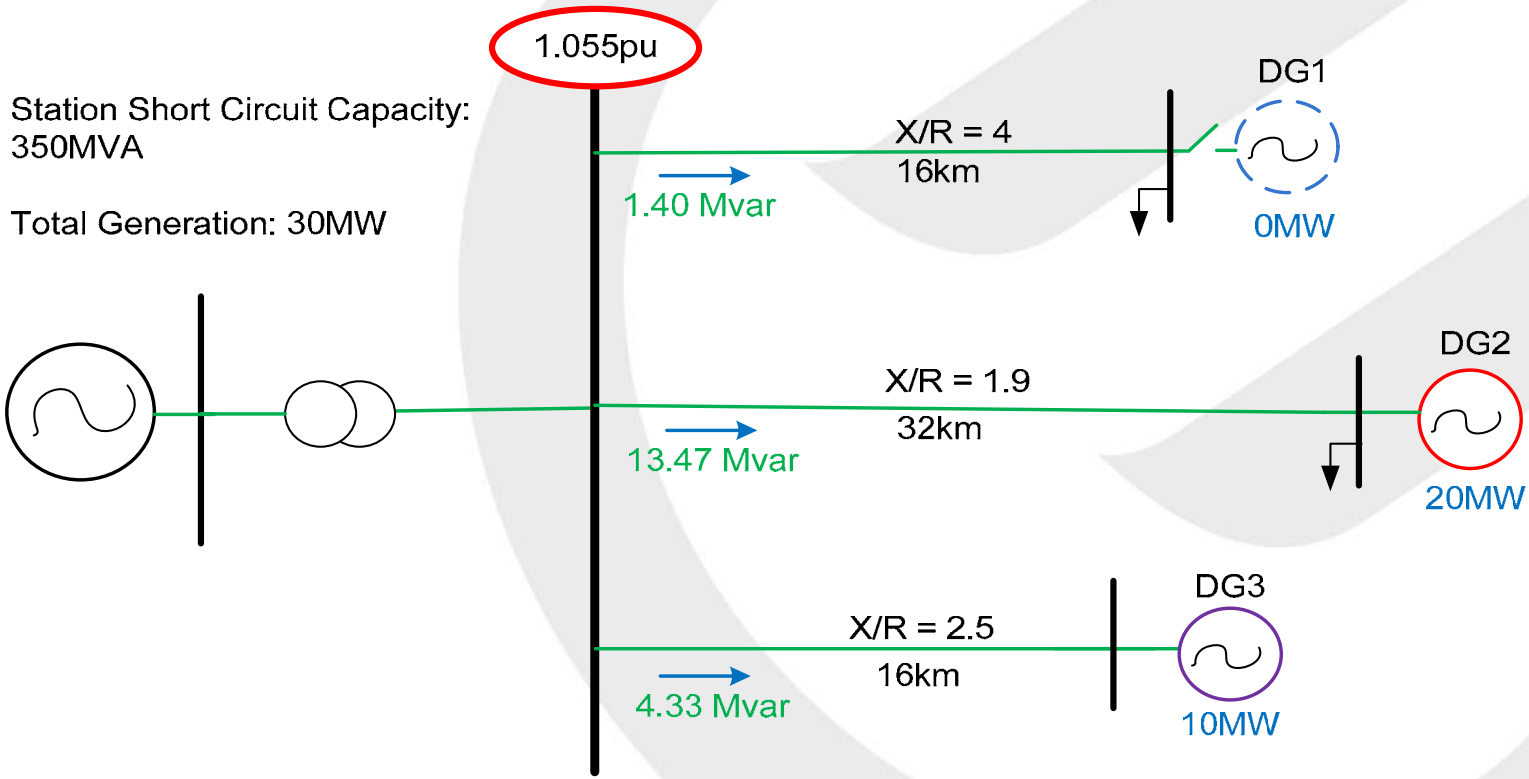
Comments

- The station level performance criteria will
  - avoid customer complaints due to excessive voltage fluctuations
  - prevent excessive operation of voltage regulating facilities
  - prevent unacceptable post-contingency voltages
- Station level performance criteria constrain the DG capacity of a station from the perspective of voltage performance

Interrelationship between feeder and station level criteria

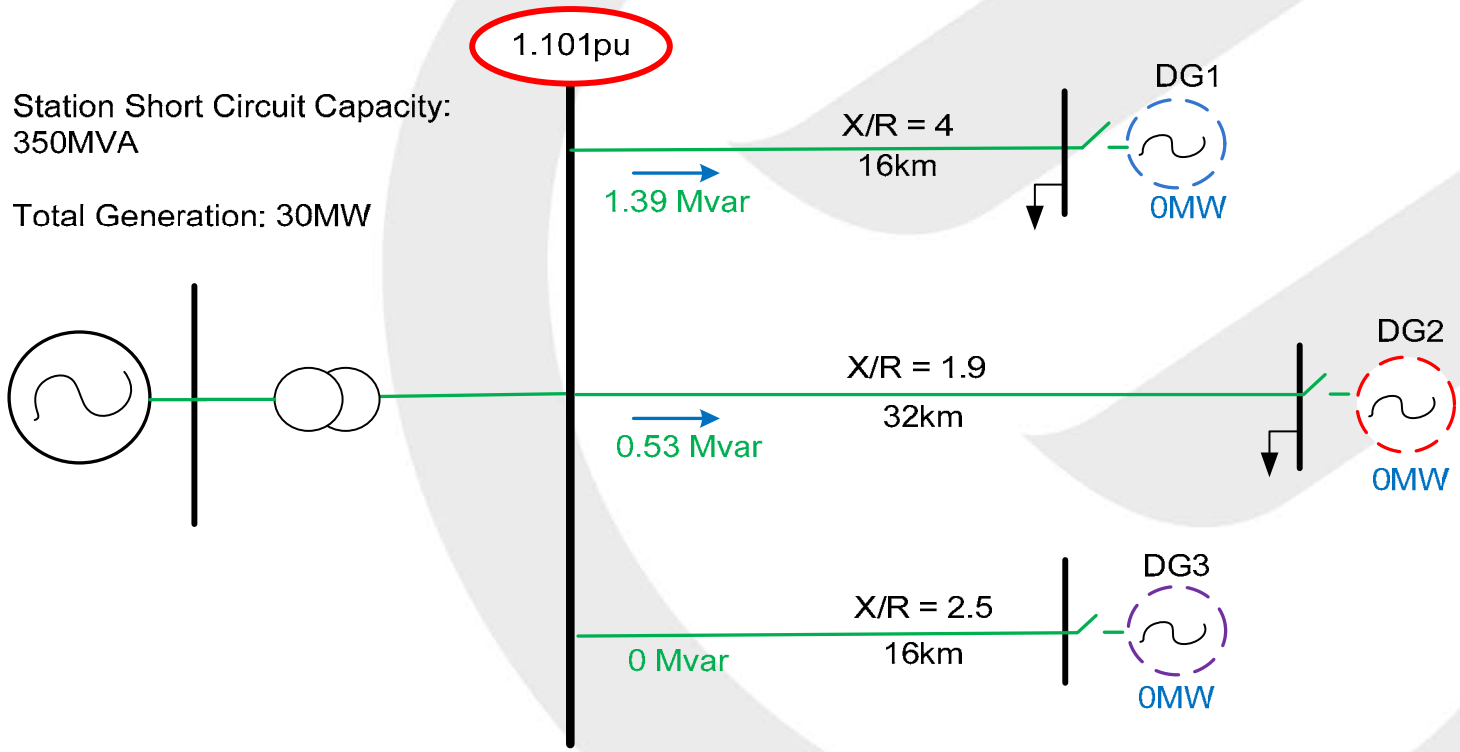
- Increasing the feeder DG capacity at the expense of violating the feeder level voltage criteria decreases the station DG capacity
- At feeder level, increasing the DG size at a given location increases the reactive power consumption attributed to the DG on per-MW basis
- However, at the station level, the total reactive power consumption attributed to DGs is limited by the station level performance criteria

Example:
Feeder DG capacity vs station capacity



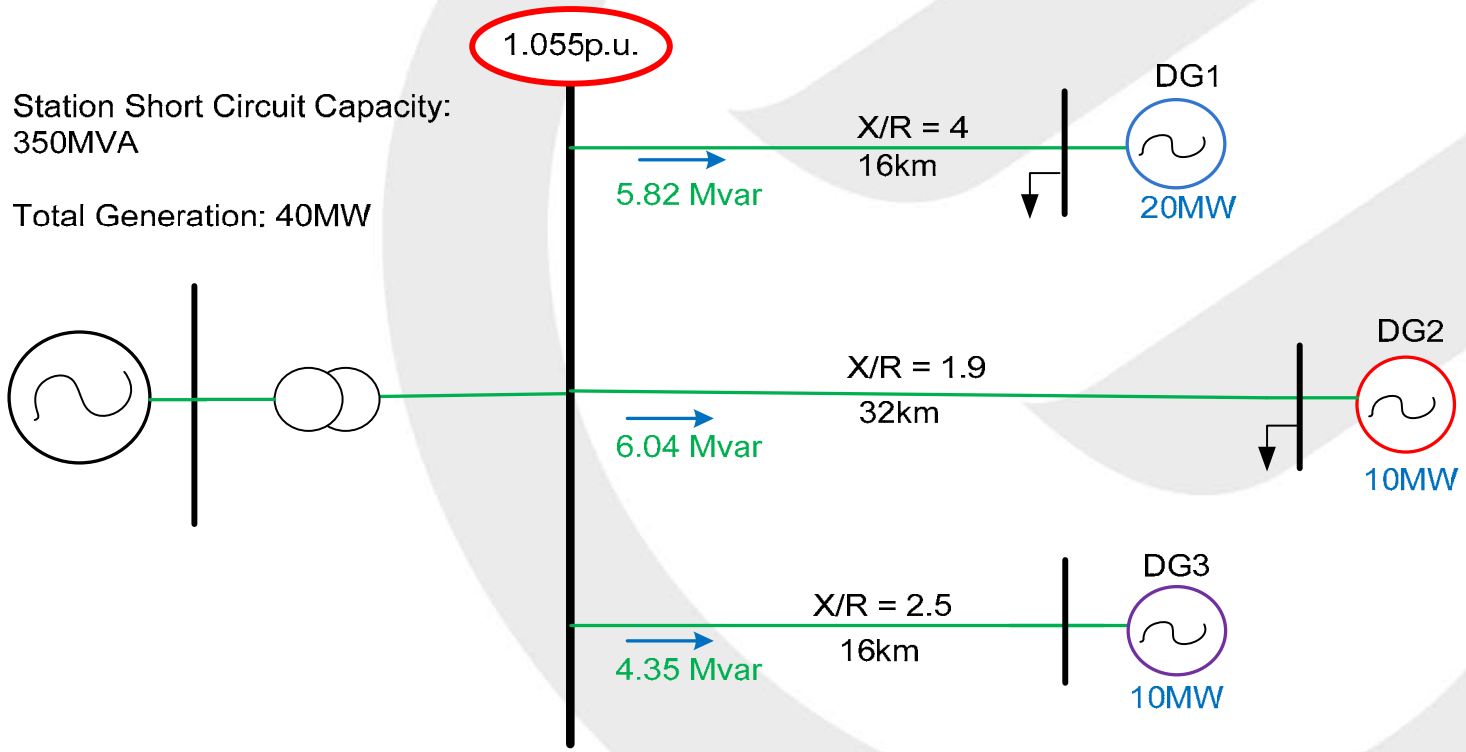
Scenario 1 – Pre-Contingency, DG2 20MW
DG2 severely violating criteria 2, 3

Example:
Feeder DG capacity vs station capacity *(cont'd)*



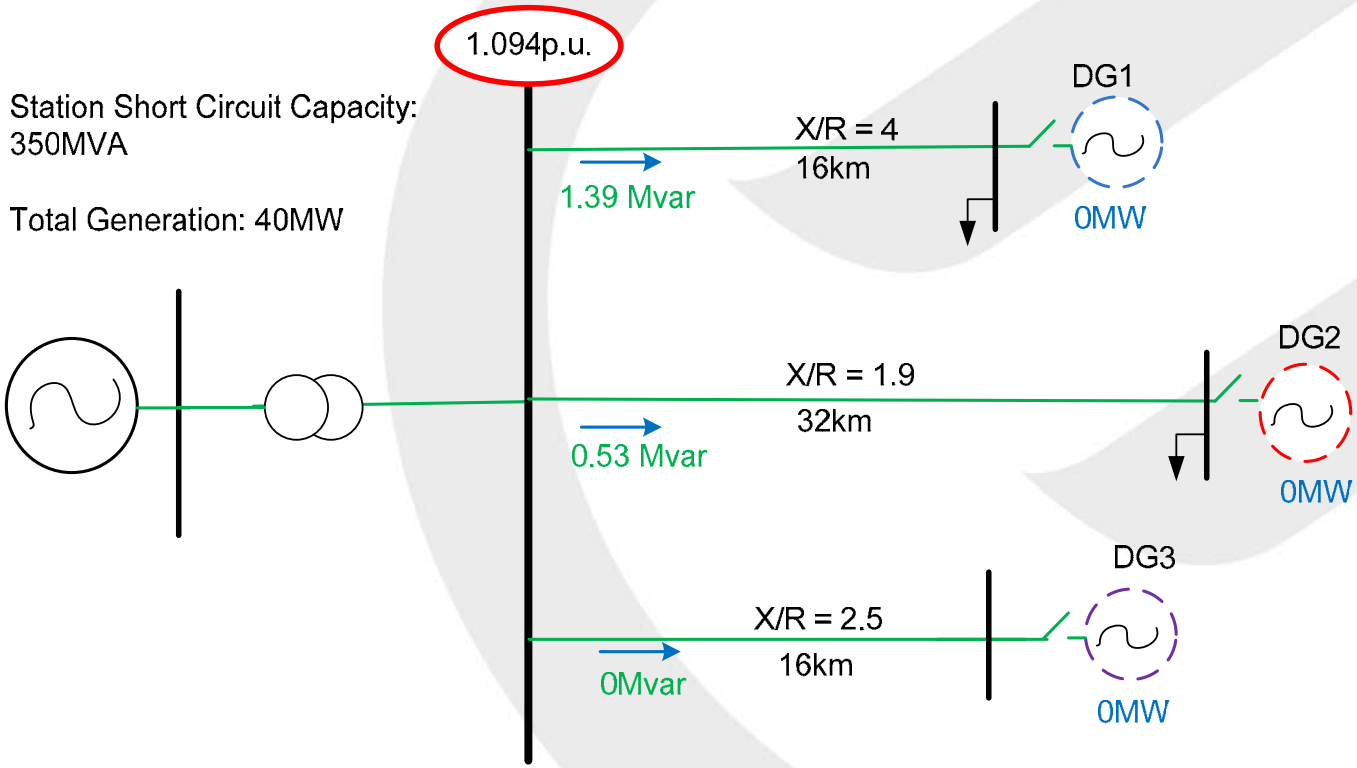
Scenario 1- after DGs trip (30MW total)
L.V. Bus Voltage >1.1p.u.

Example:
Feeder DG capacity vs station capacity *(cont'd)*



Scenario 2 – Pre-Contingency, DG2 reduced to 10MW
DG2 still violating criteria 2,3

Example:
Feeder DG capacity vs station capacity *(cont'd)*



Scenario 2 - after DGs trip (40MW total)
L.V Bus Voltage > 1.094p.u.

Interrelationship between feeder and station level criteria *(cont'd)*

Conclusions from the example

- DG2 is connected far from the station with lower X/R. It consumes more reactive power per MW to maintain feeder voltage
- Lowering the size of DG2 allows more DG connection to the station
- The example emphasizes that non-compliance with the voltage performance criteria at the feeder will constrain DG capacity at the station level

Note: Complete details of the example are attached at the end of the presentation.

Question 1

How far from the station is considered too far?

- The answer depends very much on the overall X/R ratio
- In distribution system, electrical distance is represented by both resistance and reactance
- Hydro One feeder (13.8kV -44kV) reactance is about 0.4 ohm/km, but feeder X/R ratio ranges from 1 to 4

Question 1 *(cont'd)*

How far from the station is considered too far?

- The high resistive component of the impedance causes PCC voltage to rise due to DG power output. For a given physical distance, this voltage rise is higher if X/R ratio is lower, and hence the feeder appears to be "electrically longer"

- There are other factors such as station short circuit strength, feeder loading conditions

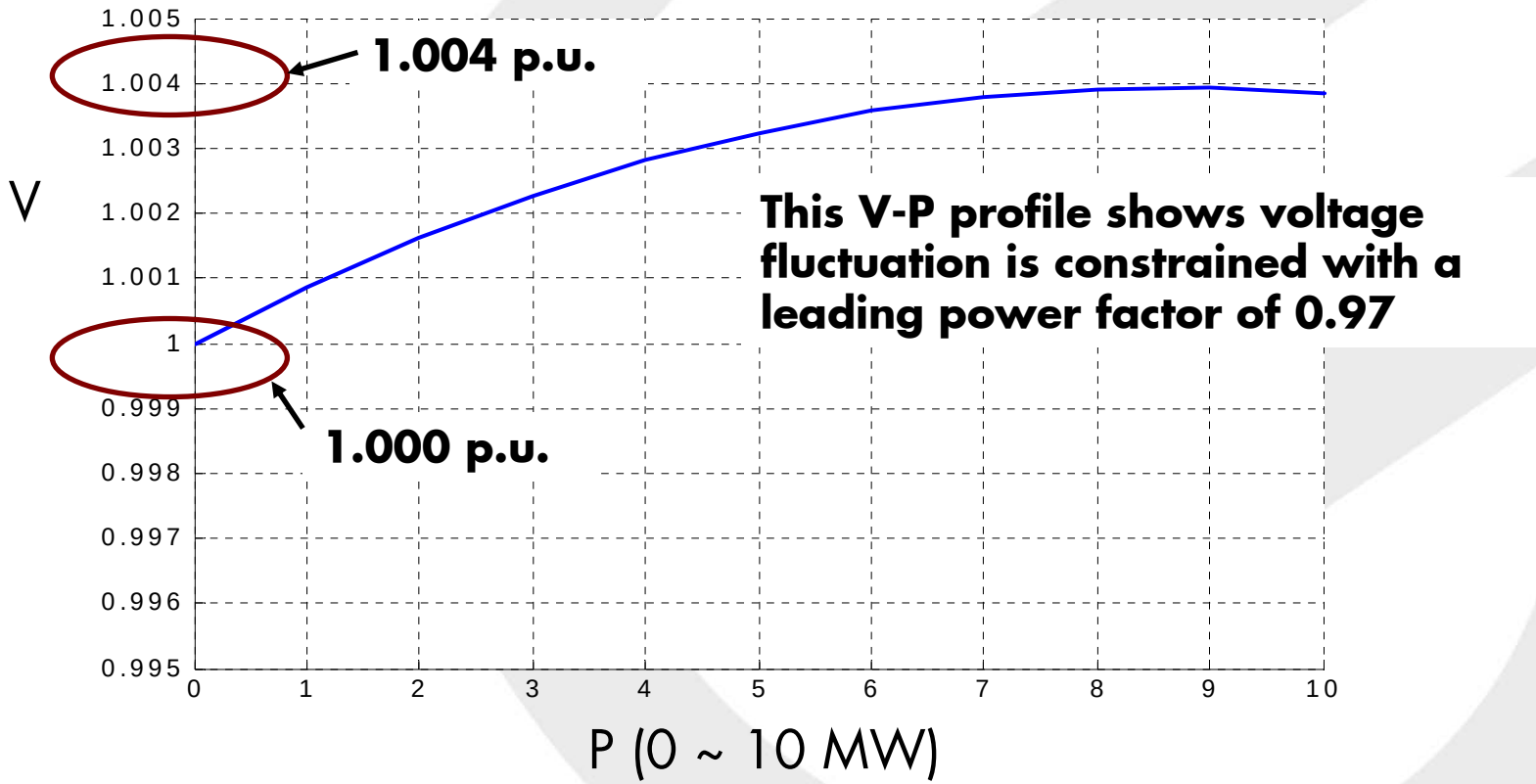
Question 2

How can voltage fluctuation be limited without voltage control?

- Both published technical literature and our own findings confirm that constant power factor control can limit voltage fluctuation
- Hydro One will assign PCC power factor according to specific system conditions
- Example: Consider a 10MW DG connected 15 km away from station with overall X/R ratio at PCC of 2.5

Question 2 *(cont'd)*

How can voltage fluctuation be limited without voltage control?



Voltage fluctuation is limited by constant power factor control

Question 3

Is voltage control with limited reactive power acceptable ?

The question proposes to:

- Exercise DG voltage control with “limited” reactive power in order to limit post-contingency voltage deviation.
- This proposal has some disadvantages as outlined in the next slide

Question 3 *(cont'd)*

Is voltage control with limited reactive power acceptable ?

Disadvantages of the Proposal

- Voltage control responds to both load and generation variations. The limited reactive power available for voltage control will likely be used to respond to load, leaving insufficient reactive power to accommodate generation
- More reactive power consumption will be needed to accommodate the same amount of generation at light load conditions. This will decrease the station DG capacity to respect post-contingency (DGs trip) voltage requirement

Question 4

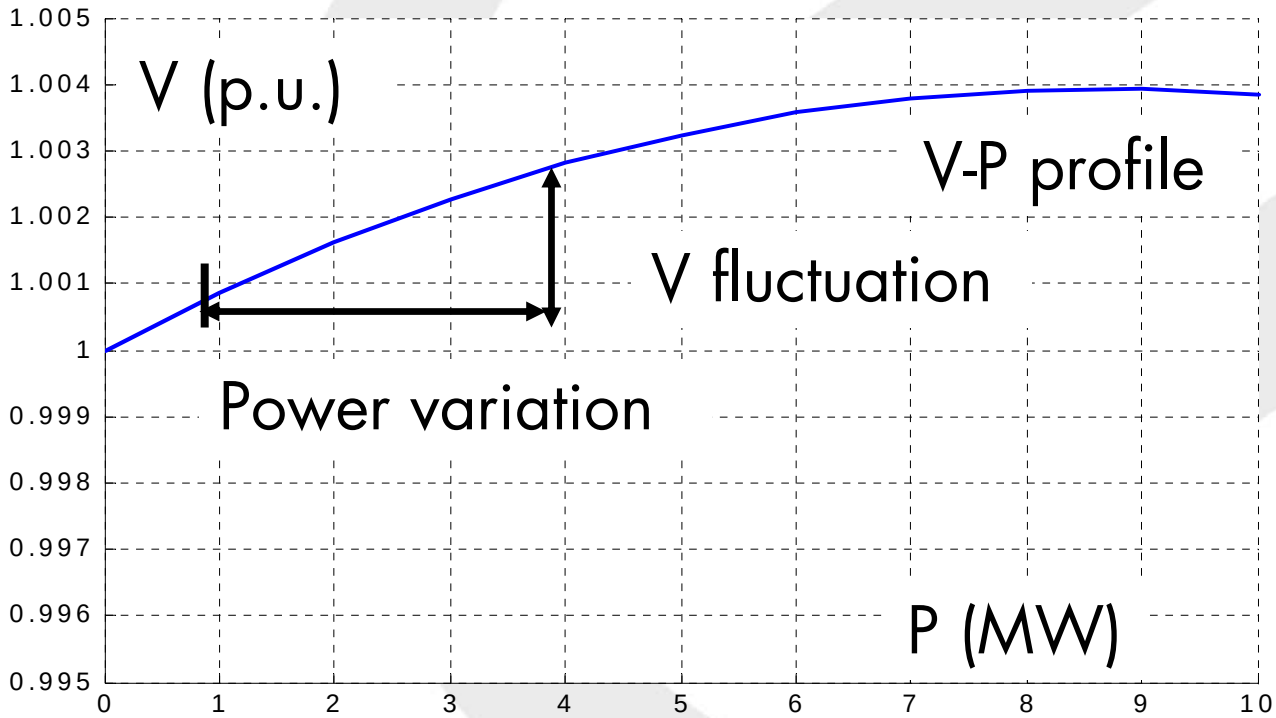
What is short term voltage fluctuation?

- Here short term voltage fluctuation refers to the voltage fluctuation caused by DG power variation as opposed to that caused by slow load variation. The time-frame is within minutes

- Hydro One uses voltage-power profiles to evaluate the short term fluctuation. We monitor real power variations of existing DG plants, then use the level of power variations to find the voltage fluctuation on the voltage-power profiles

Question 4 *(cont'd)*

What is short term voltage fluctuation?



Question 5

Will a power factor range at the PCC be acceptable ?

- Hydro One requires constant power factor operation at the PCC for all DG output conditions to limit voltage fluctuation and maintain acceptable voltage profile
- Hydro One determines the power factor settings according to system conditions
- Hydro One will not specify a power factor range

Feedback Process

- Additional questions and/or feedback regarding the addendum will be accepted for a period of one week
- Please use the following e-mail address to communicate your comments

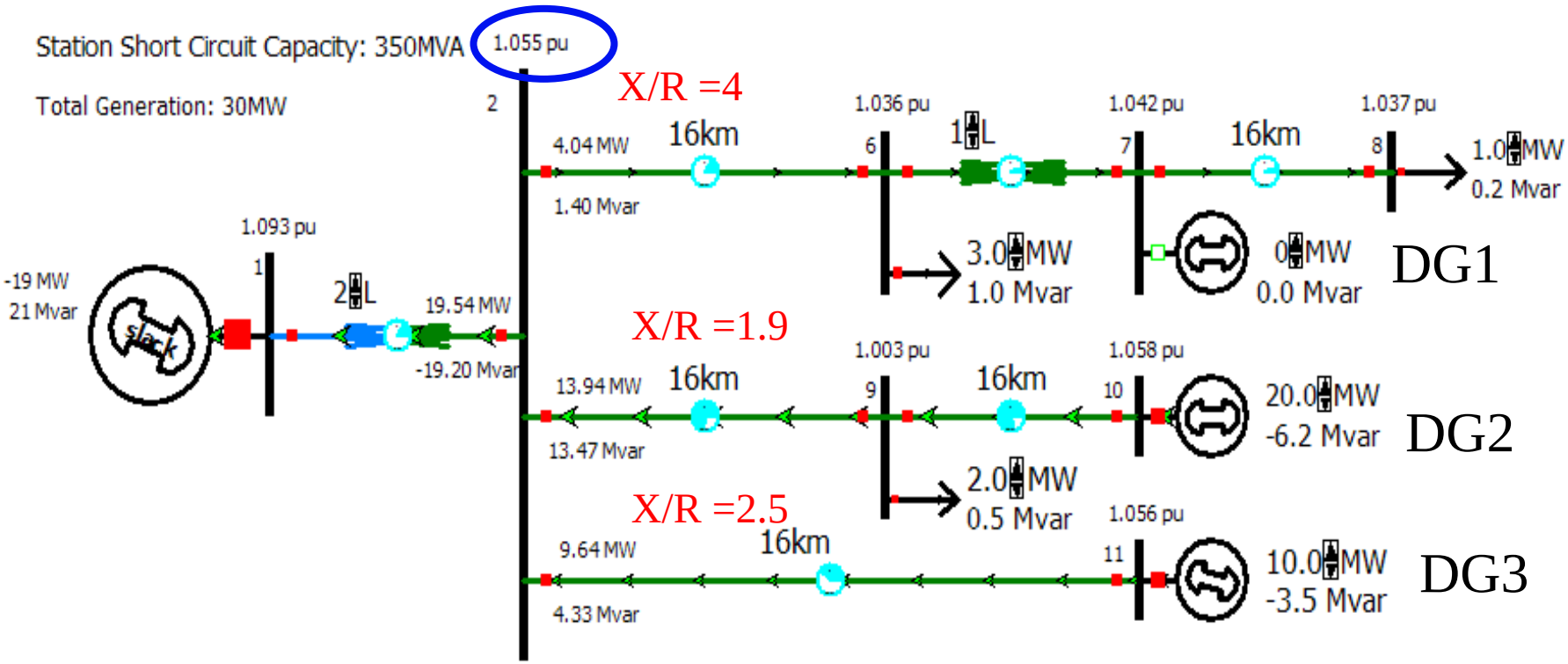
DGConnectionReq@HydroOne.com

Questions?

Please submit your questions on today's webinar topic "Distribution Voltage Performance Criteria and Requirements"

For questions unrelated to today's webinar, please contact your local Hydro One Account Executive or email your question to DGConnectionReq@HydroOne.com

Example:
Feeder DG capacity vs station capacity



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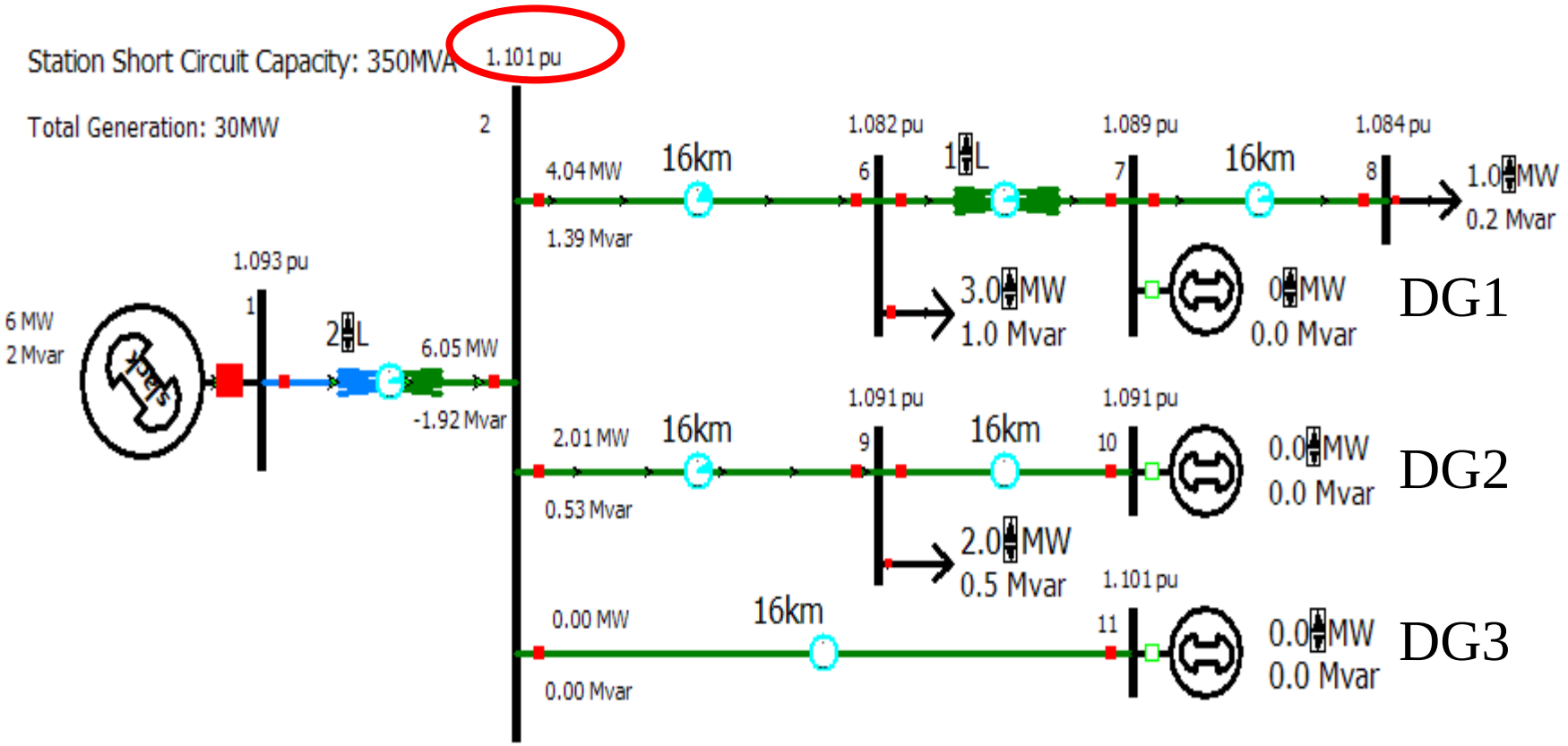
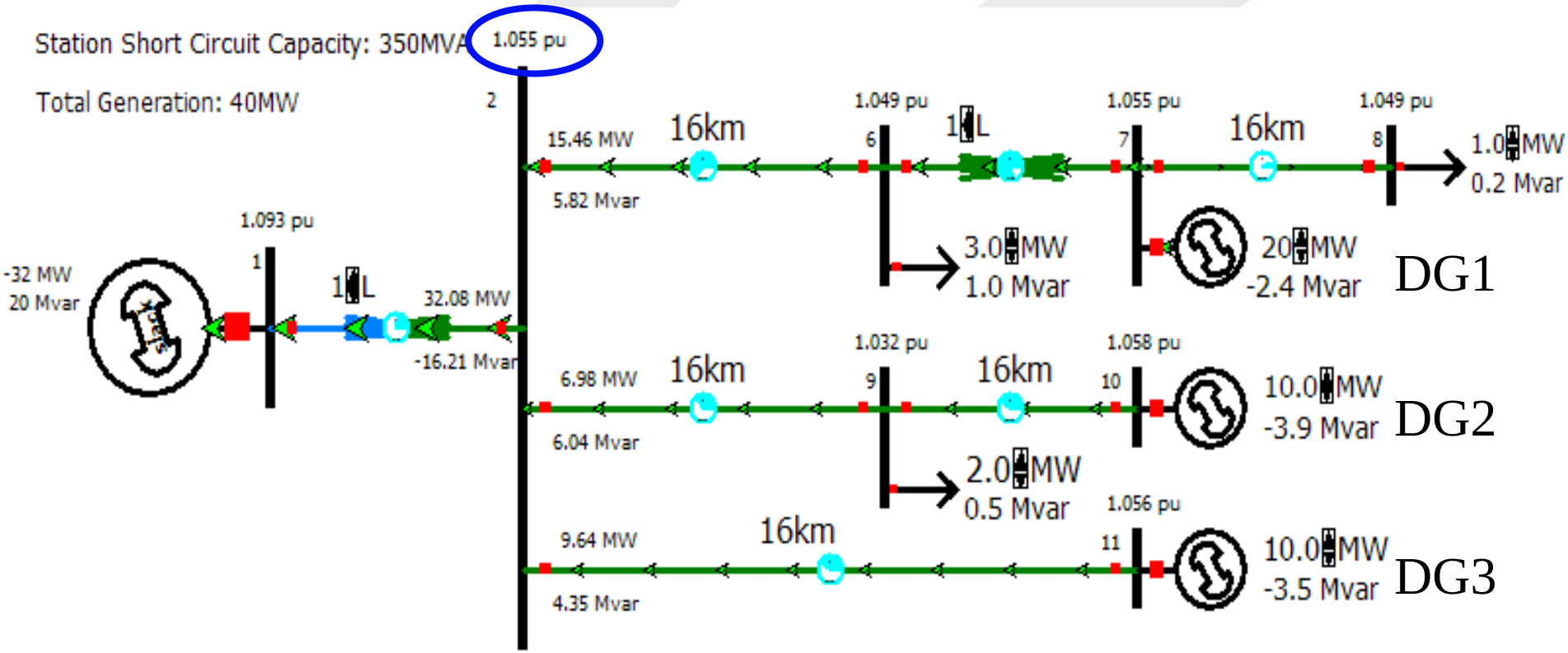


LV bus voltage >1.1 p.u. after DGs trip (total 30 MW)

Example:
Feeder DG capacity vs station capacity *(cont'd)*



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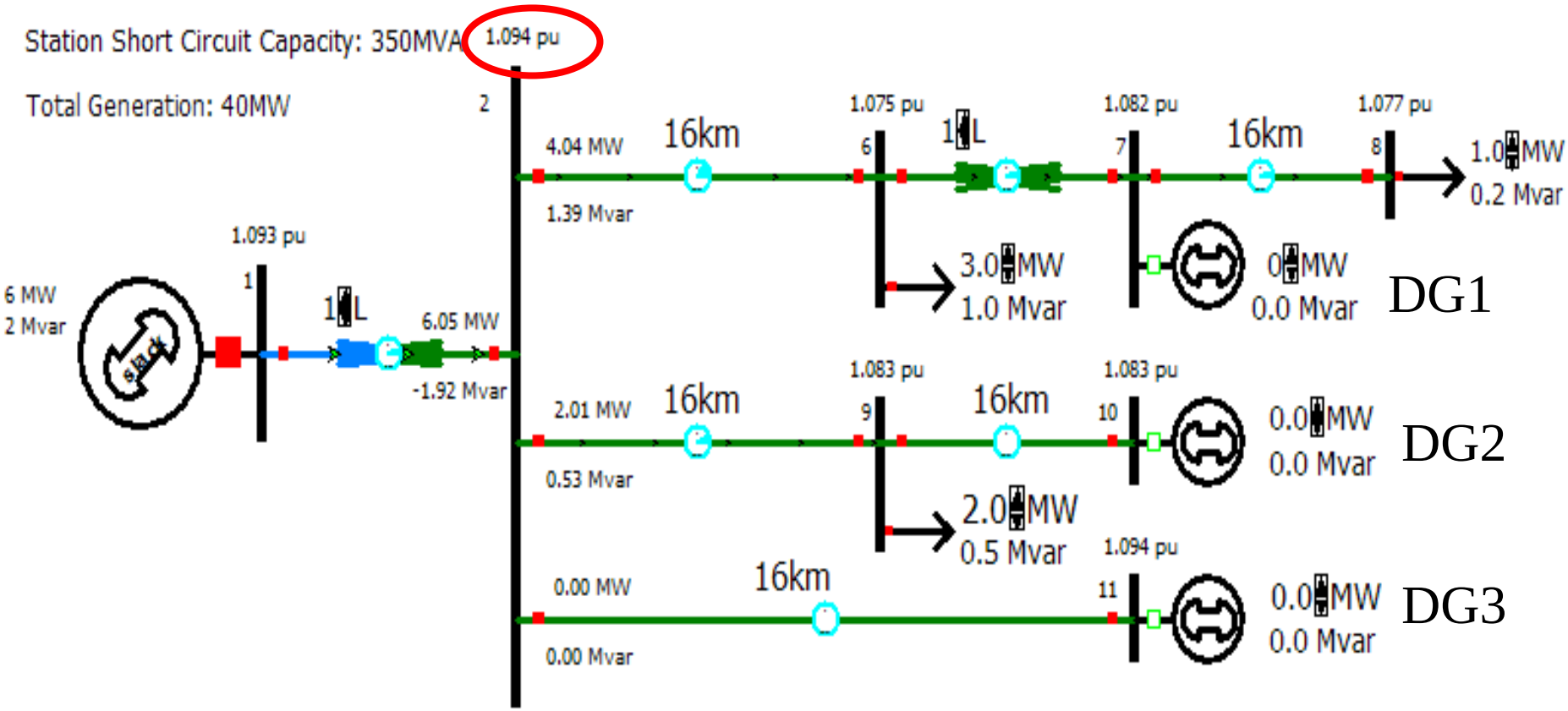
DG2 reduced to 10 MW

Example:
Feeder DG capacity vs station capacity *(cont'd)*



LV bus voltage 1.094 p.u. after DGs trip (total 40 MW)