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Experience Sharing on Distribution Level Impacts of DPV in Thailand

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Outline

Experience sharing on distribution level impacts of DPV in Thailand

- **Thailand DPV Penetration**
- **Evaluation of Thailand's Pilot Net-Metering Project**
- **Thailand utility (PEA) DPV impact**

Experience sharing on distribution level impacts of DPV in Thailand

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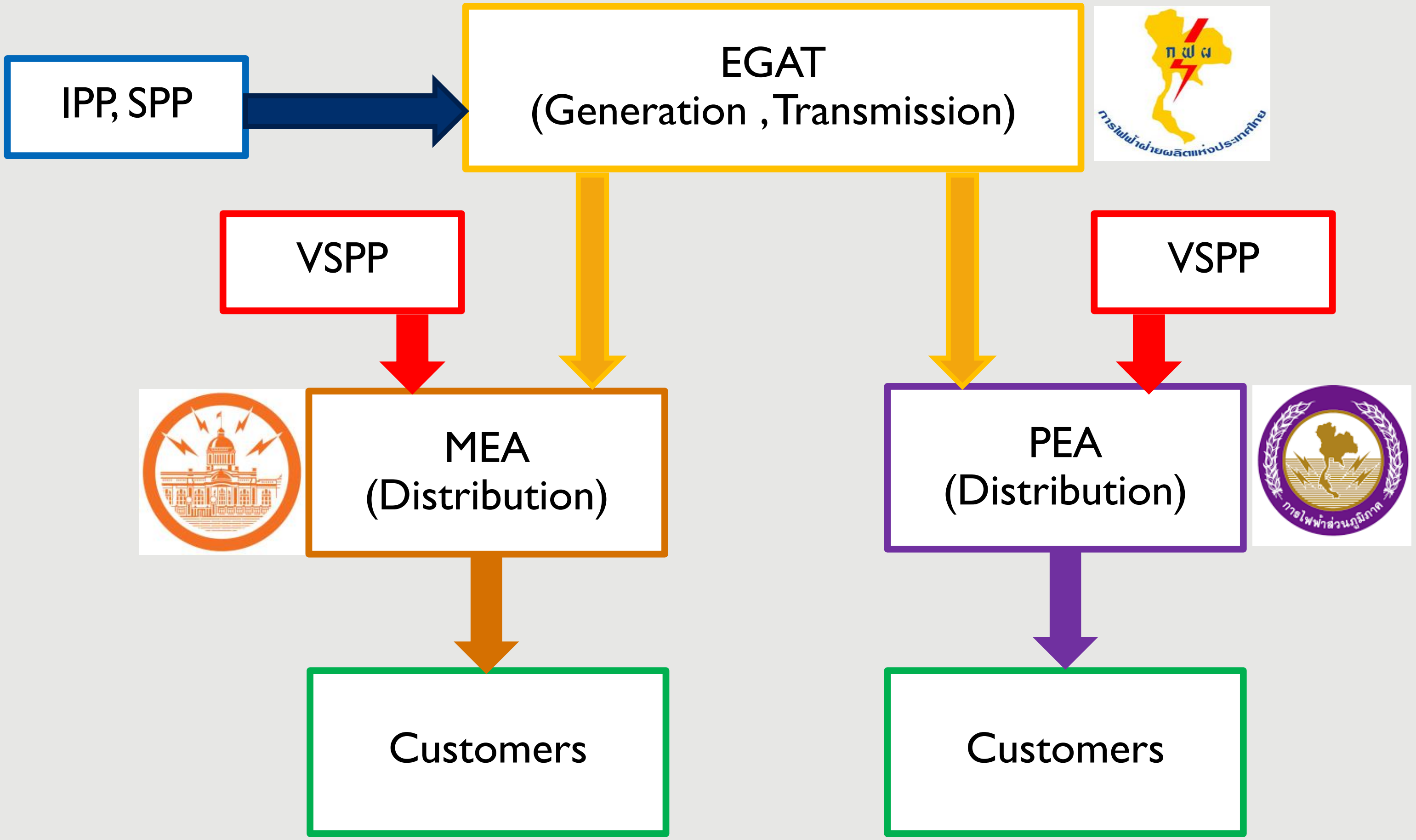
Thailand DPV penetration

Thailand Electricity Supply Structure



Thailand DPV penetration

In Thailand, DG can be categorized as follows

(ref: purchasing announcement)

- Independent Power Producer (IPP) - Cap. > 90 MW

- Small Power Producer (SPP) - Cap. between 10 and 90 MW
    - Cogeneration, Firm
    - Renewable, Firm
    - Non-firm

- Very Small Power Producer (VSPP) - Cap. □ 10 MW
    - Cogeneration
    - Renewable

DPV

Thailand DPV penetration

Examples of DPV supporting policies

- Adder

  Adder is additional rate for buying energy from private renewable energy resource company on top of the normal electricity tariff, for a fixed period of time (years).

- Feed in Tariff (FiT)

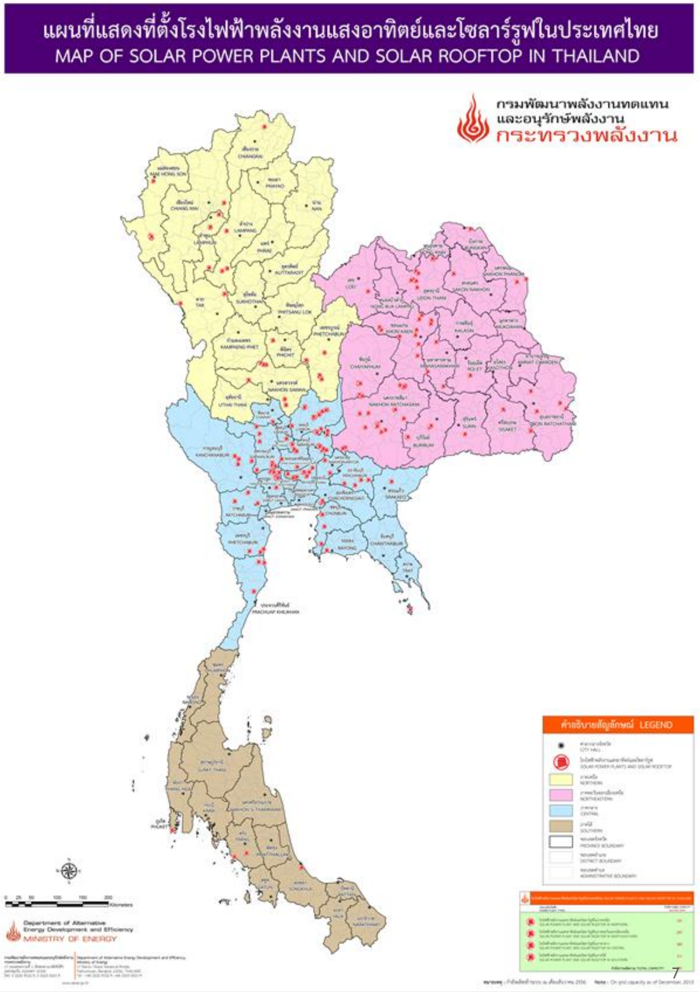
  FiT is extra rate for buying energy from private renewable energy resource company, constant over the lifetime of renewable energy project.

Thailand DPV penetration

- **Map of Solar Power Plants and Solar Rooftop in Thailand (2018)**

Type	Number of Projects	Installation (MW)	Contract capacity (MW)
SPP	7	588.64	436.00
VSPP	523	2195.07	2,130.02
Total	**530**	**2,783.71**	**2,566.02**
Target	**x**	**x**	**6,000.00**

According to Alternative Energy Development Plan 2015 (AEDP2015), the target for installation of Solar Power Plants and Solar Rooftop in Thailand is 6,000 MW in 2036.



Thailand DPV penetration

Grid code : PEA penetration limit

<table>
<tr><th rowspan="2">Regulation</th><th colspan="4">Voltage of PEA Distribution System</th></tr>
<tr><th>115 kV</th><th>33 kV</th><th>22 kV</th><th>220/380 V</th></tr>
<tr><td>MEA Grid code 2015 (SPP & VSPP)</td><td rowspan="2">120 MW/feeder (Single Conductor)

230 MW/feeder (Double Conductor)</td><td rowspan="2">10 MW/Feeder
&
75% of transformer rated</td><td rowspan="2">8 MW/Feeder
&
75% of transformer rated</td><td rowspan="2">5 kW/Feeder
&
15% of transformer rated</td></tr>
<tr><td>Solar PV Rooftop 2016 context</td></tr>
<tr><td>Solar PV Rooftop 2013 context</td><td>-</td><td colspan="2">-</td><td>25% of transformer rated</td></tr>
</table>

Thailand DPV penetration

Grid code : MEA penetration limit

<table>
<tr><th rowspan="2">Regulation</th><th colspan="5">Voltage of MEA Distribution System</th></tr>
<tr><th>115 kV</th><th>69 kV</th><th>24 kV</th><th>12 kV</th><th>230/400 V</th></tr>
<tr><td>MEA Grid code 2015 (SPP & VSPP)</td><td>180 MW/Feeder</td><td>90 MW/Feeder</td><td rowspan="3">8 MW/Feeder
&
20% of transformer rating</td><td rowspan="3">4 MW/Feeder
&
20% of transformer rating</td><td rowspan="2">5 kW/phase
&
15% of transformer rating</td></tr>
<tr><td>Solar PV Rooftop 2016 context</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Solar PV Rooftop 2013 context</td><td>10 kW/phase
&
15% of transformer rating</td></tr>
</table>

Thailand DPV penetration

Grid code : MEA & PEA Voltage limit

Utility	Voltage level (kV)	Minimum voltage (kV / p.u.)	Maximum voltage (kV / p.u.)
MEA	24	21.8 / 0.9083	23.6 / 0.9833
	0.400 (230 volt)	0.371 / 0.9275	0.410 / 1.0250
PEA	22	20.9 / 0.9500	23.1 / 1.0500
	0.380 (220 volt)	0.342 / 0.9000	0.418 / 1.1000

Experience sharing on distribution level impacts of DPV in Thailand

- Thailand DPV Penetration
- **Evaluation of Thailand's Pilot Net-Metering Project**
- Thailand utility (PEA) DPV impact

Evaluation of Thailand's pilot net-metering project

Objectives:

- Understand the technical impacts of increasing DPV on the distribution grid (focusing on voltage, loss, and peak reduction)
- Determine the penetration limits of DPV
- Determine how the grid code can be improved in order to accommodate a higher DPV penetration

Evaluation of Thailand's pilot net-metering project

Policy context: Increasing DPV in Thailand power systems

Stakeholders:

Thailand Ministry of Energy, Energy Regulatory Commission, Distribution Utilities

Findings:

Recommendations on grid codes and how utilities can technically prepare for supporting an increase in DPV

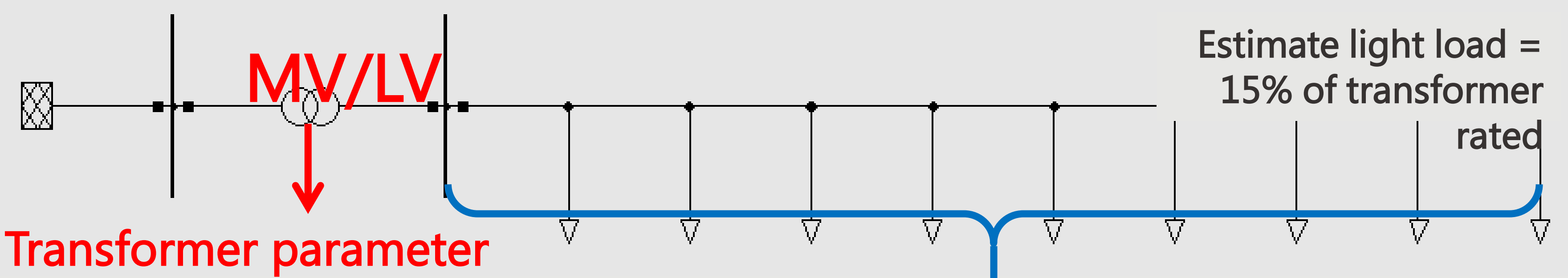
Evaluation of Thailand's pilot net-metering project

Approach:

- Establish a typical electrical power distribution system (Circuit System and Power Line)
- Consider the minimum power demand (light load) that occurs in the electrical system to simulate the case in which reverse power flow most likely happens.
- Voltage limits and electrical power loss change are the criteria for determining the maximum installed capacity.
- Test the installation position at the beginning of the line, the center of the line and the end of the line by calculating the maximum installed capacity. (Maximization Problem) in each position.
- Compare the maximum installed capacity generated by the voltage criterion and the power loss criterion.

Evaluation of Thailand's pilot net-metering project

Low Voltage simulation model



Transformer parameter

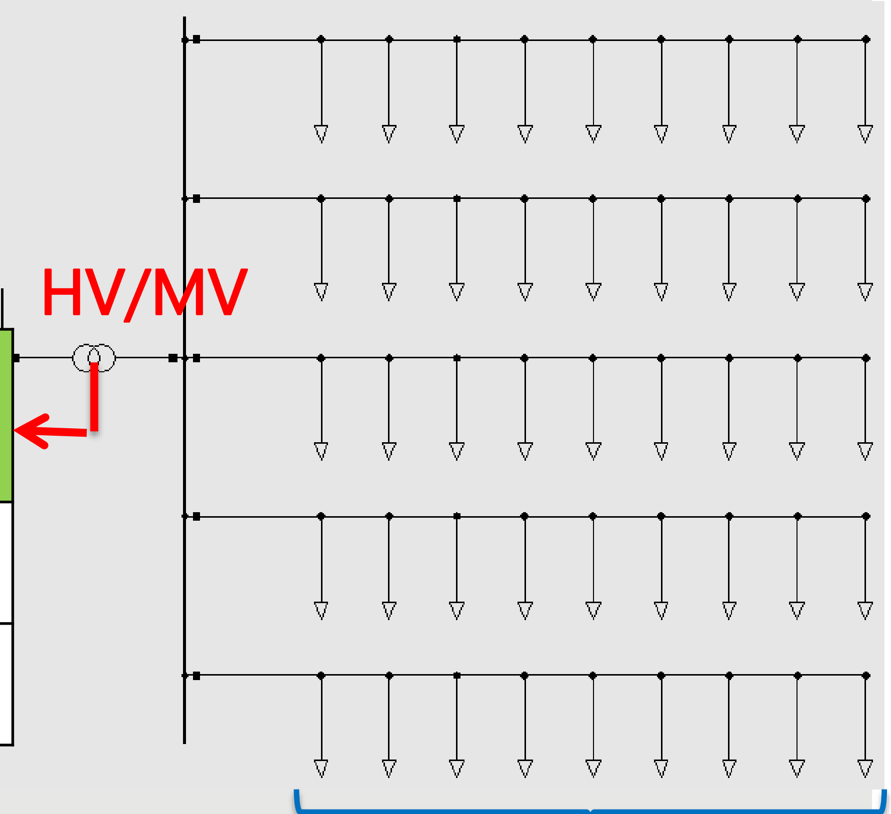
Utility	Rated (kVA)	Voltage (kV)	Resistance (p.u.)	Reactance (p.u.)
MEA	150	24/0.400	0.00670	0.03940
PEA	100	22/0.380	0.00670	0.04955

Line parameter

Utility	Current (kA)	Voltage (kV)	Resistance (ohm/km)	Reactance (ohm/km)	Length (km)
MEA	0.11	0.400	0.5414	0.2625	0.500
PEA	0.10	0.380	0.8664	0.1149	1.000

Evaluation of Thailand's pilot net-metering project

Medium Voltage simulation model



Transformer parameter

Utility	Rated (kVA)	Voltage (kV)	Resistance (p.u.)	Reactance (p.u.)
MEA	60	112/23.04	0.00393	0.20000
PEA	50	115/23.10	0.00300	0.14997

Line parameter

Utility	Current (kA)	Voltage (kV)	Resistance (ohm/km)	Reactance (ohm/km)	Length (km)
MEA	0.390	24	0.20000	0.29500	8.37104
PEA	0.429	22	0.21065	0.41140	46.60000

Estimate light load = 20% of transformer rated

Evaluation of Thailand's pilot net-metering project

Grid code : MEA & PEA Voltage limit

Utility	voltage level (kV)	Minimum voltage (kV / p.u.)	Maximum voltage (kV / p.u.)
MEA	24	21.8 / 0.9083	23.6 / 0.9833
	0.400 (230 volt)	0.371 / 0.9275	0.410 / 1.0250
PEA	22	20.9 / 0.9500	23.1 / 1.0500
	0.380 (220 volt)	0.342 / 0.9000	0.418 / 1.1000

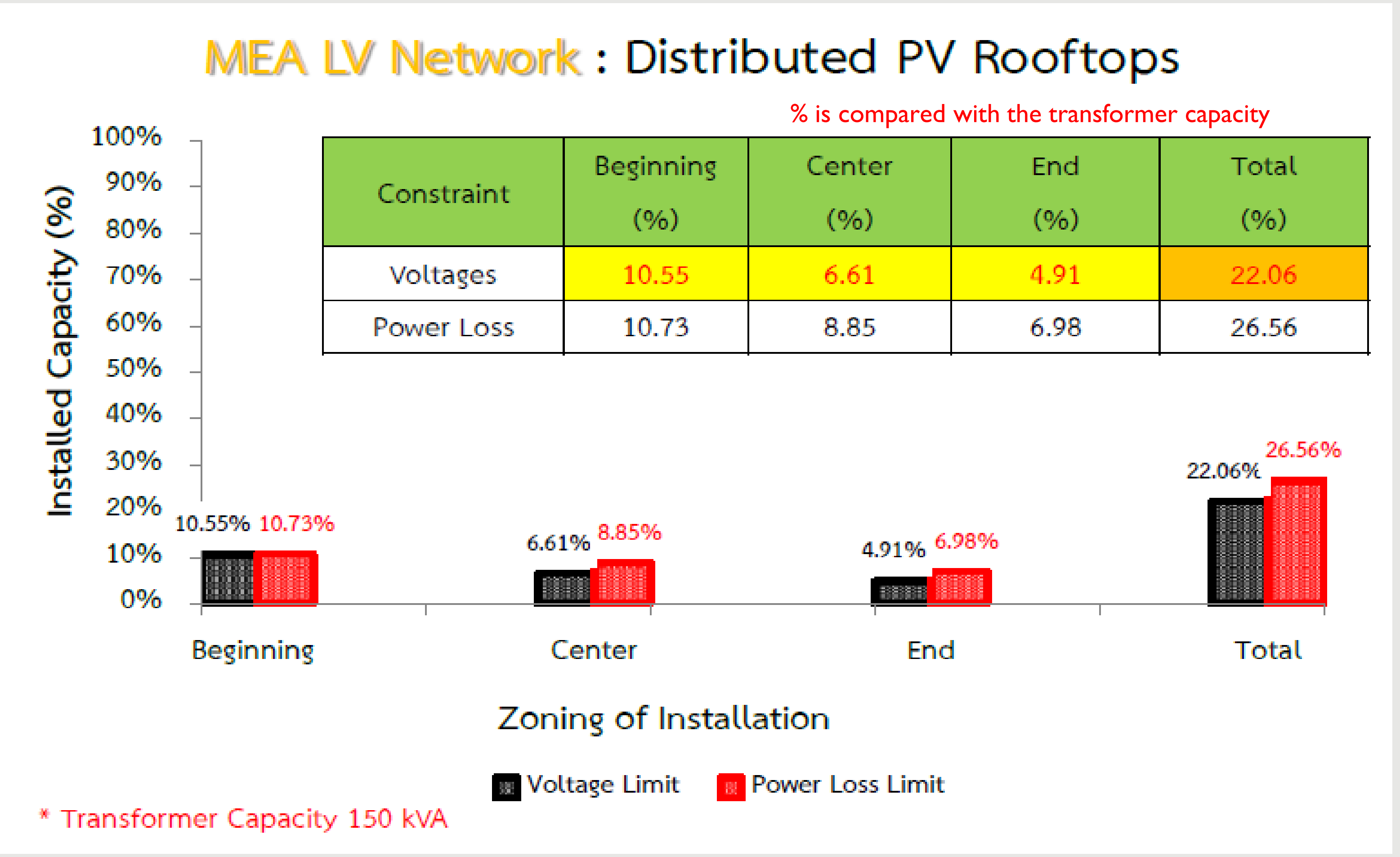
The acceptable amount of electrical power loss change

Utility	Power loss before installed Solar PV Rooftop	
MEA	24 kV	230/400 V
	0.5738 MVA (from 36 MVA, 1.59%)	0.4468 kVA (from 90 kVA, 0.50%)
PEA	22 kV	220/380 V
	0.6268 MVA (from 30 MVA, 2.09%)	0.5709 kVA (from 60 kVA, 0.95%)

Evaluation of Thailand's pilot net-metering project

Example of Results from the Study in Thailand:

Acceptable DPV Penetration under Voltage and Loss Limits



Constraint	Beginning (%)	Center (%)	End (%)	Total (%)
Voltages	10.55	6.61	4.91	22.06
Power Loss	10.73	8.85	6.98	26.56

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Thailand utility (PEA) DPV impact

Simulation model :Voltage and loss in medium voltage system

Using the example of PEA medium voltage system to analyze.

System parameters

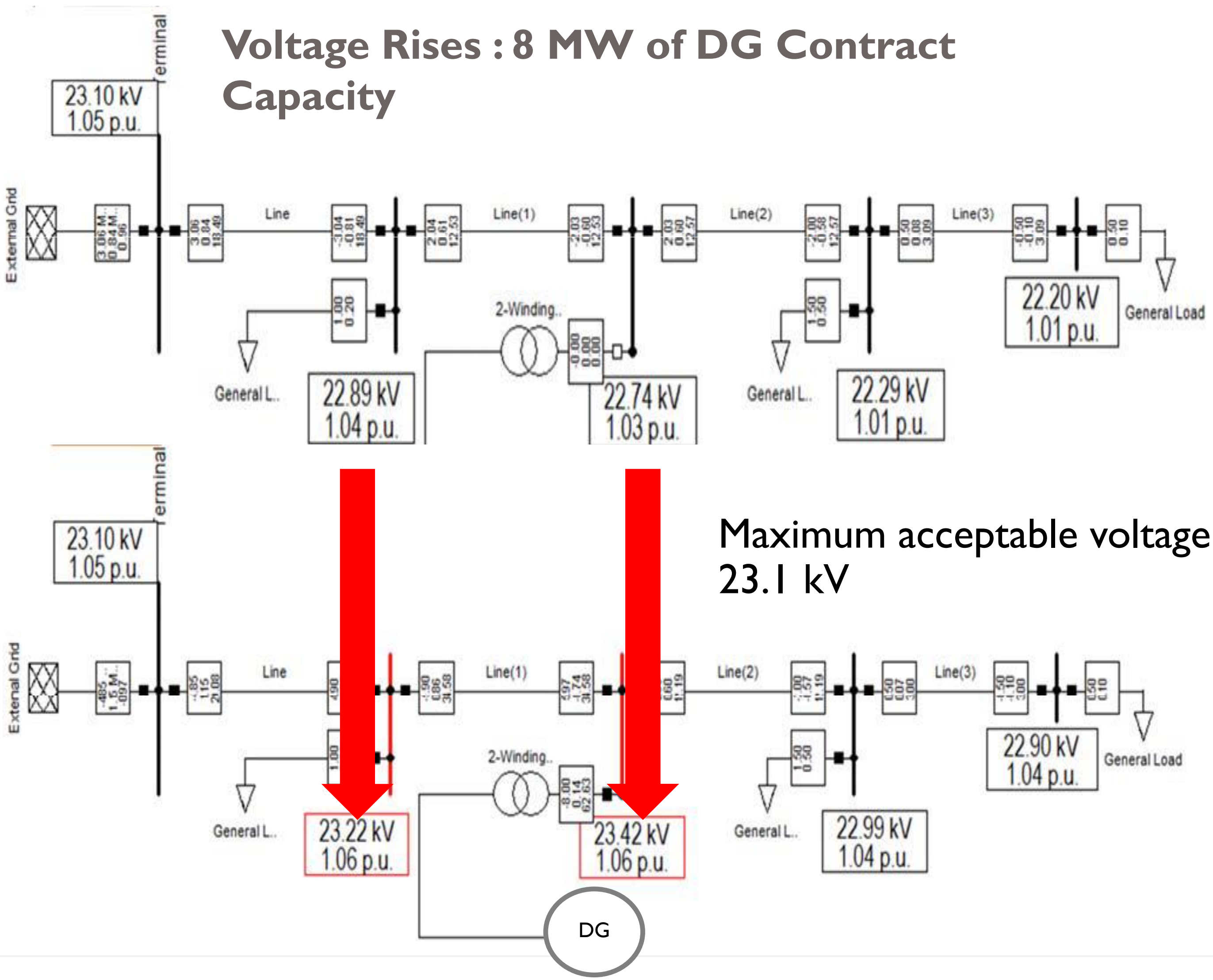
voltage level (kV)	Transformer Voltage (kV)	Maximum Acceptable Voltage (kV)	Line current Rated (kA)	Resistance (ohm/km)	Reactance (ohm/km)
22	115/23.10	23.10	0.429	0.21065	0.41140

Thailand utility (PEA) DPV impact

Voltage Rises : 8 MW of DG Contract Capacity

Before Install DG

After Install DG

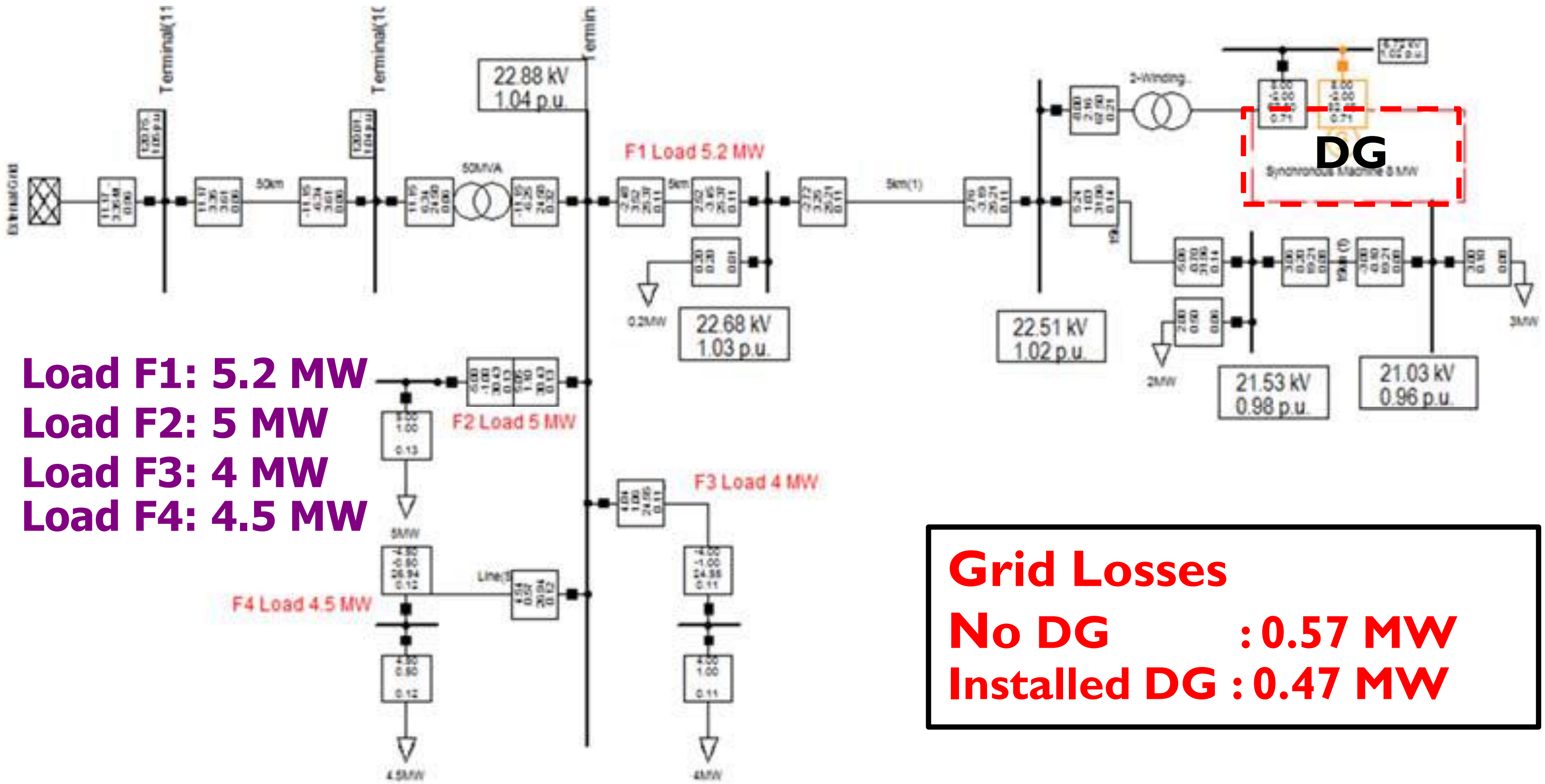


Maximum acceptable voltage is 23.1 kV

Thailand utility (PEA) DPV impact

Decrease of Power and Energy Losses

DG supply : 8 MW

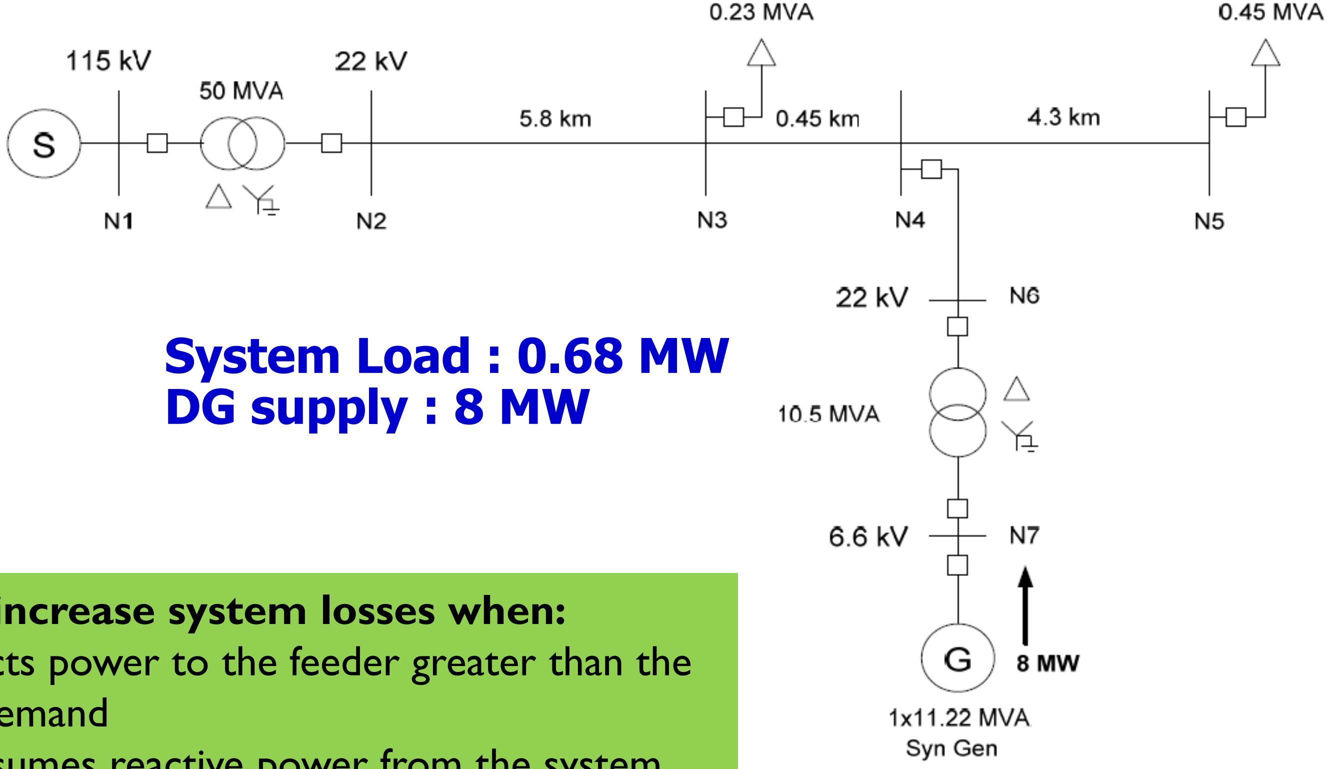


Load F1: 5.2 MW
Load F2: 5 MW
Load F3: 4 MW
Load F4: 4.5 MW

Grid Losses
No DG : 0.57 MW
Installed DG : 0.47 MW

Thailand utility (PEA) DPV impact

Increase of Power and Energy Losses



System Load : 0.68 MW
DG supply : 8 MW

DG may increase system losses when:
- DG injects power to the feeder greater than the feeder demand
- DG consumes reactive power from the system
- DG operates in a PQ mode, or does not support reactive power

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