IMPACT OF DISTRIBUTION GENERATION ON VOLTAGE RISE AND POWER LOSSES IN PEA 22KV DISTRIBUTION SYSTEM

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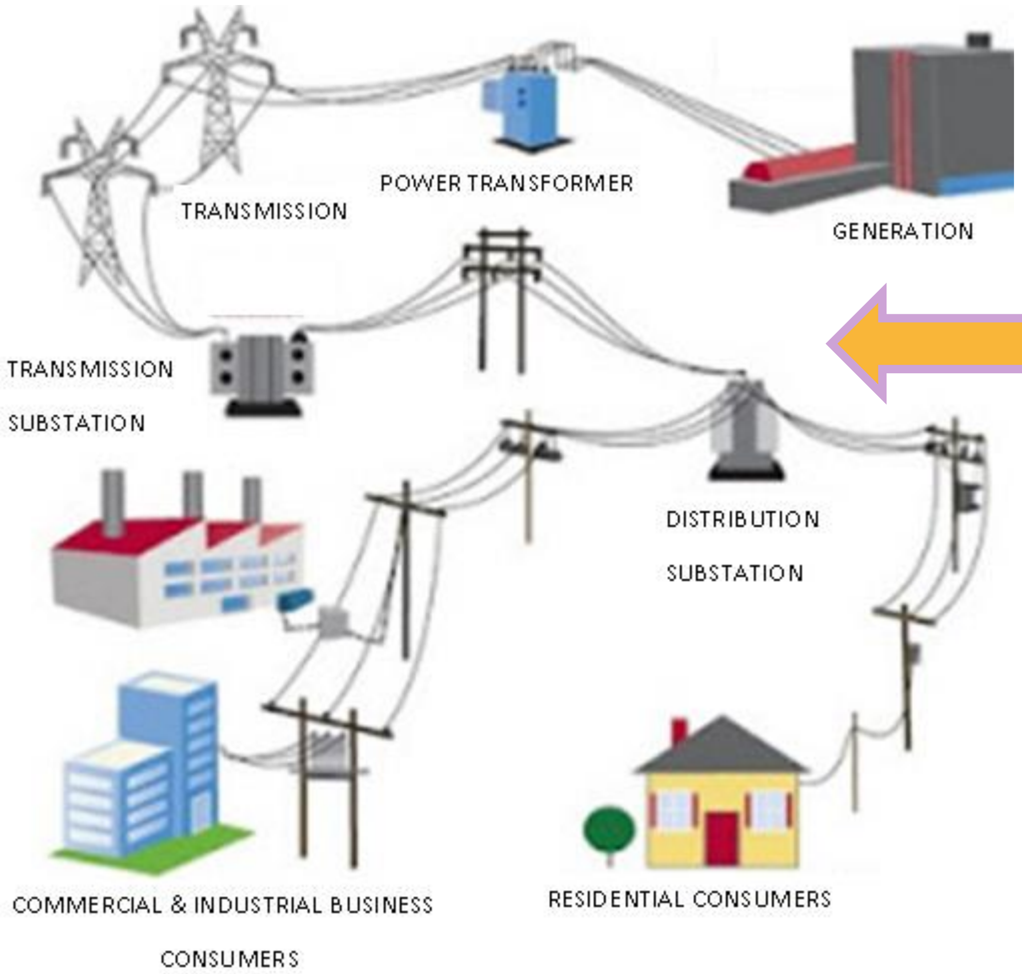
DISTRIBUTION SYSTEM

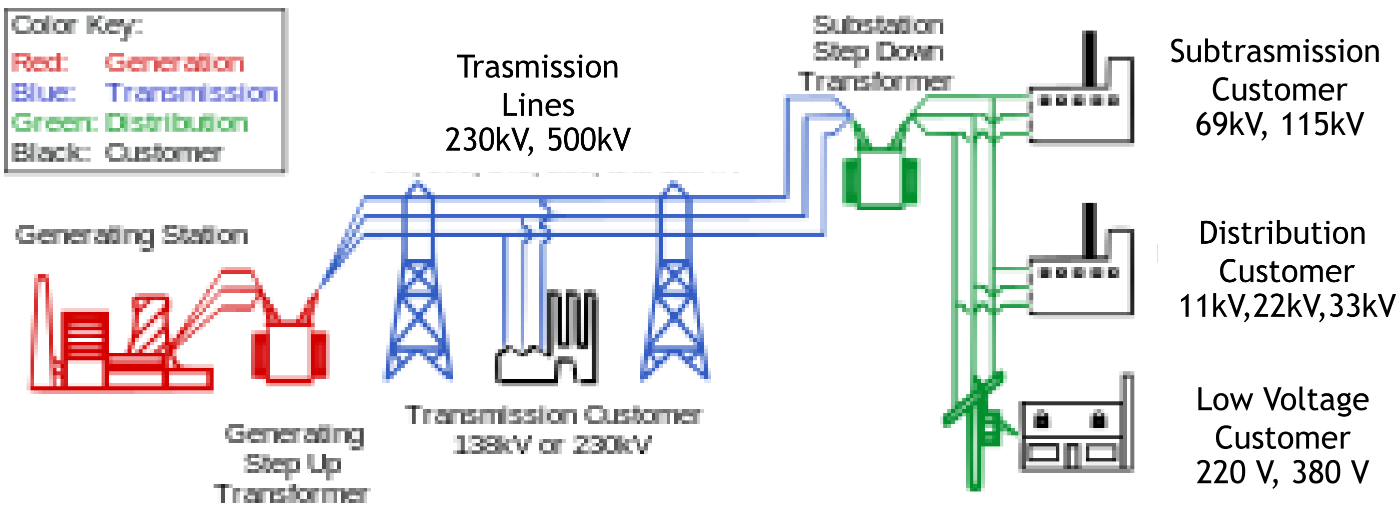


Distributed Generation

Connected to Grid

POWER FLOW DIRECTION

Traditional Distribution Network



The power flow is in one direction only, from the transmission system to the HV substations and to the MV&LV distribution system.

The voltage decrease along the feeder, from substation to the feeder-end.

VOLTAGE RISE EFFECT

The power voltage at DG will increase voltage, which may cause the voltage at its connection point to be higher that voltage at the substation.

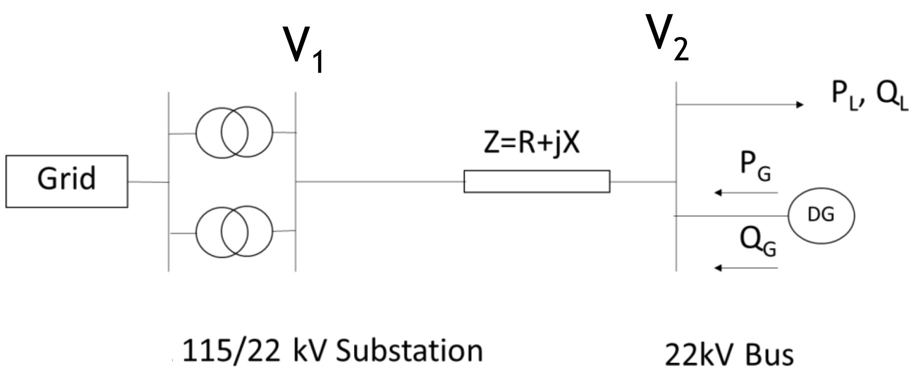
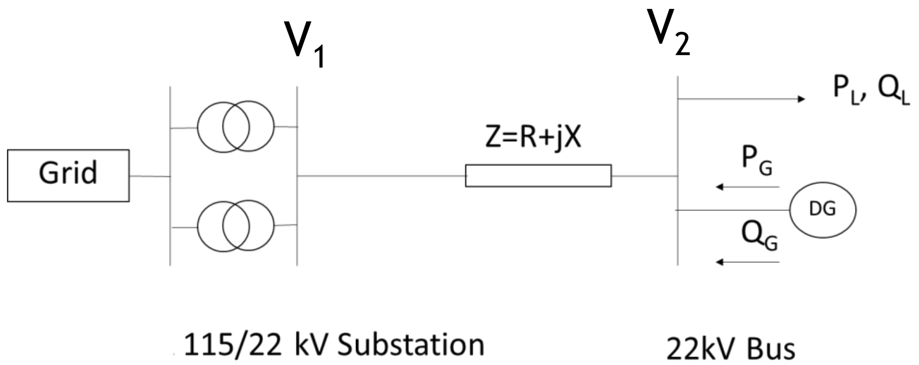


Figure 1 Illustration of a DN with DG connected

This circuit represents the basic features of a DN in which DG is connected to a DN feeder.

$$V_2 \approx V_1 + R(P_G - P_L) + (\pm Q_G - Q_L)X \quad \text{(Eq.1)}$$

This simple equation can be used to qualitatively analyze the relationship Between the voltage at 22 kV Bus and the amount of generation that can be connected to the DN.



Normally, before allowing the installation of DG, the Distribution System Operation will ensure that the voltage, line thermal characteristics and substation transformer capacity will not be violated for the worst operating scenarios:

1) No generation and maximum load
2) Maximum generation and maximum load
3) Maximum generation and minimum load

POWER LOSS ANALYSIS

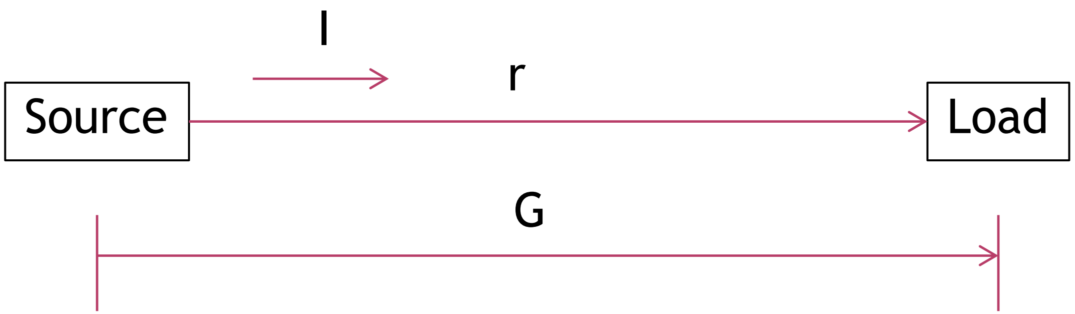


Figure 3 Simple model of Distribution system

A simple model of the distribution system long G km.

r : Resistance of line (Ω/km)

$$Power_{Source} = Load + Power\ Loss \quad \text{(Eq.2)}$$

$$Power\ Loss = I^2 rG \quad \text{(Eq.3)}$$

POWER LOSS IN SYSTEM WITH DG

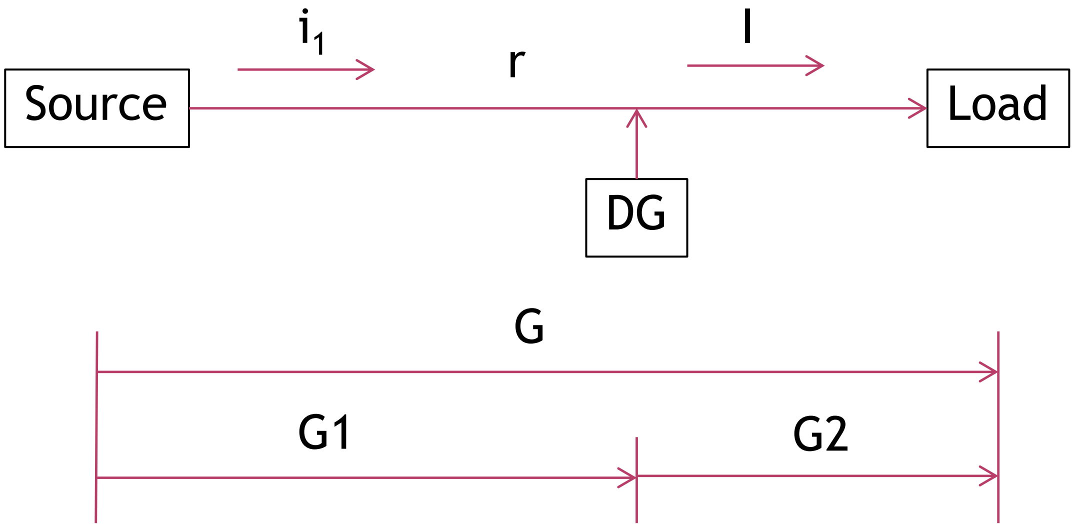


Figure 4 Simple model of Distribution system with DG installation

$$Power\ Loss_{with\ DG} = i_1^2 r G_1 + I^2 r G_2 \qquad \text{(Eq.4)}$$

$$Power\ Loss_{with\ DG} = Power_{Source} + Power_{DG} - Load \qquad \text{(Eq.5)}$$

PEA GRID CODE FOR VSPP

Voltage level

Voltage	Normal		Contingency	
	Max	Min	Max	Min
Transmission	±5%		±10%	
115 kV	120.7	109.2	126.5	103.5
69 kV	72.4	65.5	75.9	62.1
Distribution	±5%		±10%	
33 kV	34.7	31.3	36.3	29.7
22 kV	23.1	20.9	24.2	19.8
Low Voltage	±10% Approx.		±10% Approx.	
380 V	418	342	418	342
220 V	240	200	240	200

THE STUDY SYSTEM

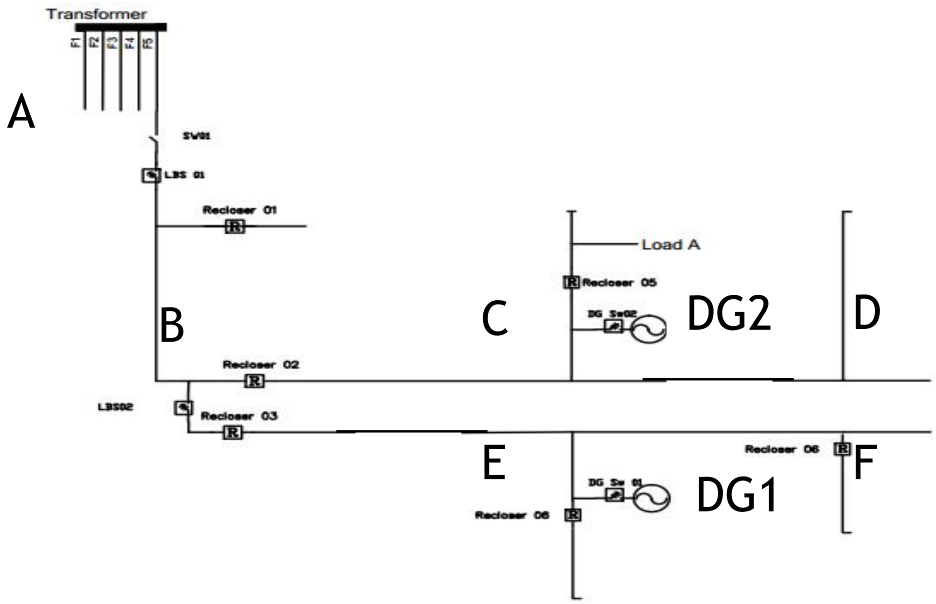
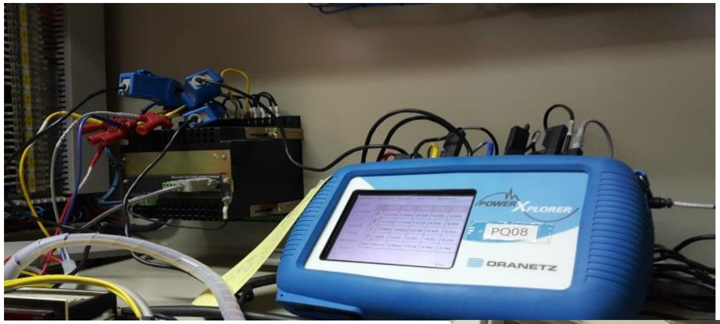


Figure 4 Radial DN 22 kV of PEA in the northeast area of Thailand

The main feeder had been divided into 2 main branches at ‘B’ and each branches protected by the line recloser.
‘C’ for connecting of DG2 (PV-DG 5.1 MW)
‘E’ for connecting of DG1 (Biomass-based DG 2.4 MW)
‘D’,’F’ the end of line.

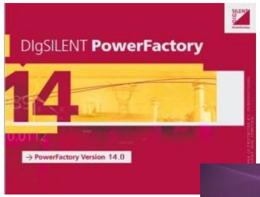
DATA COLLECTION

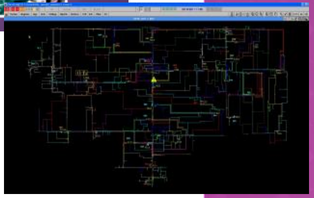
- Power quality measuring of Substation, DG1 and DG2 follow EN50160 std.
- Dranetz model Power X



SIMULATION

- DigSILENT software
- Geographic Information System (GIS)
- SCADA system
- Constant impedance load dispersed along line





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DG DATA

- DG1
  - Biomass generation rating 2.4 MW
  - Sugarcane mill factory
  - 22kV VSPP
  - Generation period during milling from Dec – Apr

- DG2
  - PV generation rating 5.1 MW
  - 22kV VSPP
  - Generation period during daytime

LOAD DATA

- Rural area, small city
- Commercial load
- Small business load
- Mining factory load
- Residential load
- Total average load 6.25 MW

DISTRIBUTION SYSTEM DATA

- Nominal Voltage: 22 kV
- Sending Set Point Voltage: 22.5±1.25%

POWER PROFILE

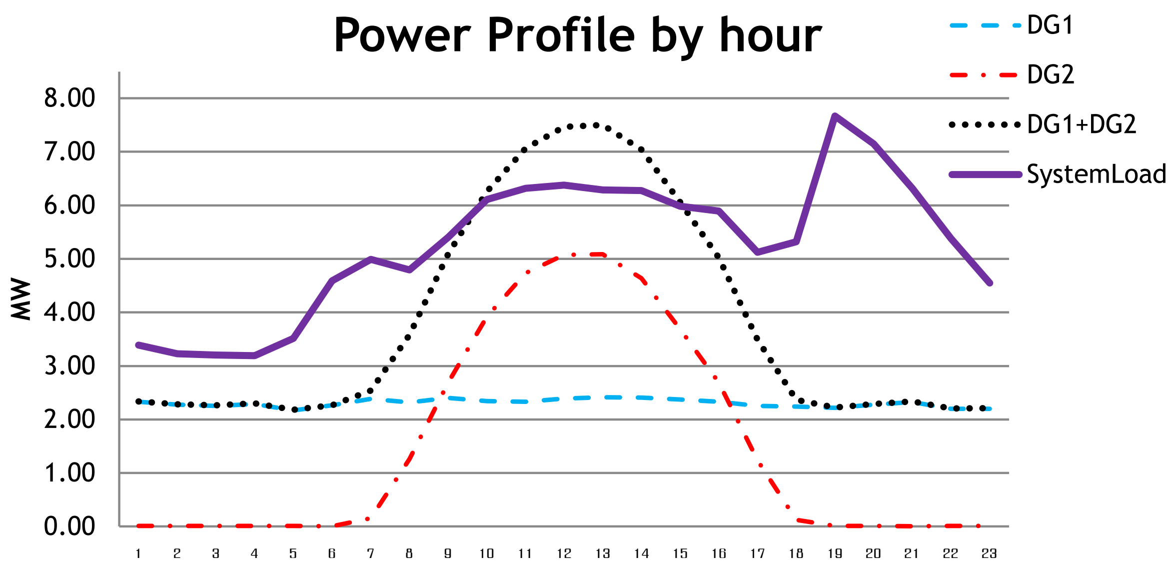


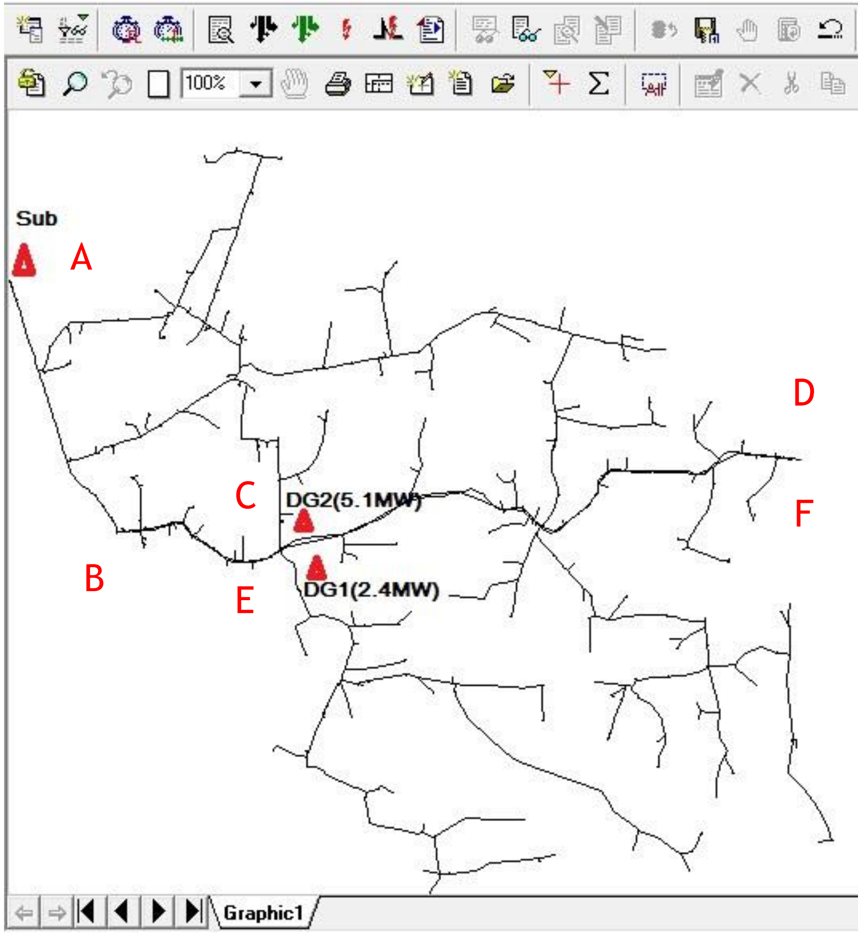
Figure 5 Power Profile of load and DG generation rating 24 hrs.

DG1 Biomass-based: generate power at 2.4 MW average
DG2 PV: generate power only day time vary by sunrise cycle, max at 5.1 MW
System load: dispersed along line, most are residential consumers.
Commercial & Business consumers: sugar factory and small business.
Peak load at night time(07.00-09.00 pm.)
By day time total load was lower than the generation of DGs.

PROCEDURE

- Network Modeling
- Scaling load follow measuring data
- Newton Raphson (Power Equation Classical) used
- Run voltage profile with load profile 24 hrs.
- Run power flow single short for voltage level by location.
  - With and without DG
  - Vary load from 25% - 150%
- Run power flow single short for power loss
  - With and without DG
  - Vary DG Ration by vary load from 0.8 to 4.8

NETWORK MODELING



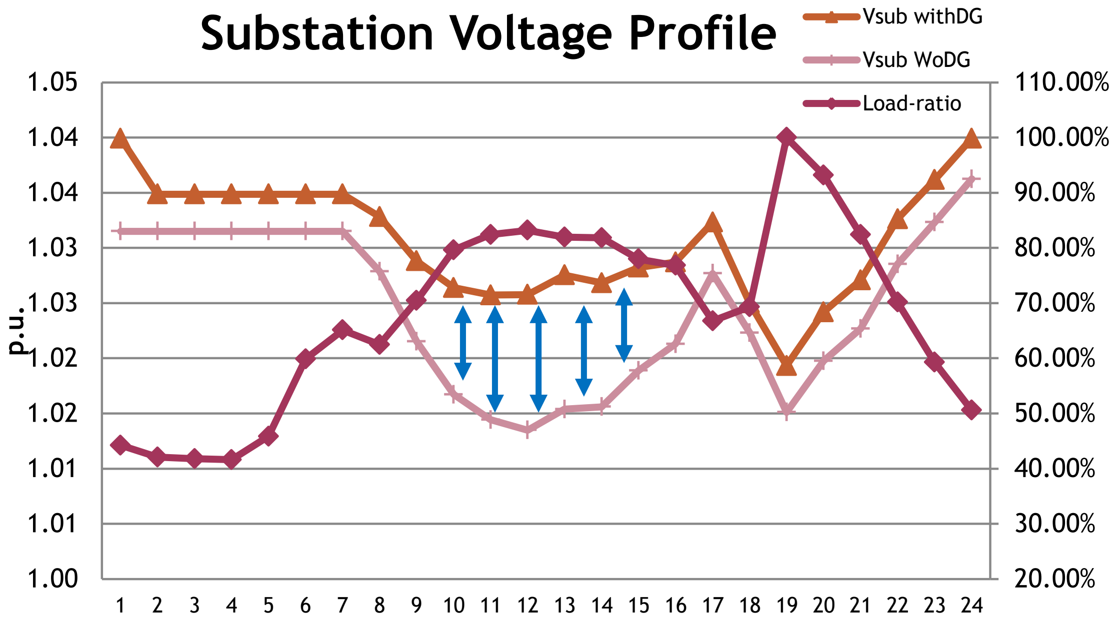
- DiSILENT Software
- Simulation data rechecked with the result from measuring data.
- Measuring data collected at 3 points: substation, DG1 and DG2.
- Collecting data period: 7 days
- Total Distribution Network length: 45 km.

Figure 6 Network modeling export from GIS

SIMULATION RESULT

VOLTAGE PROFILE

Voltage Level pu. (22kV)



%Load

Figure 7 Result of voltage profile 24 hrs. at Substation

Voltage profile at substation with and without DGs
The figure showed the voltage of system with DG was higher.
Especially during day time (09.00 am-4.00pm) with generation of the PV-DG raised significantly.
Load ratio: load/peak load (avg. of peak load in a week ≈ 6.25MW)
At peak load (Load-ratio = 100%) voltage at the substation also raised by DG.

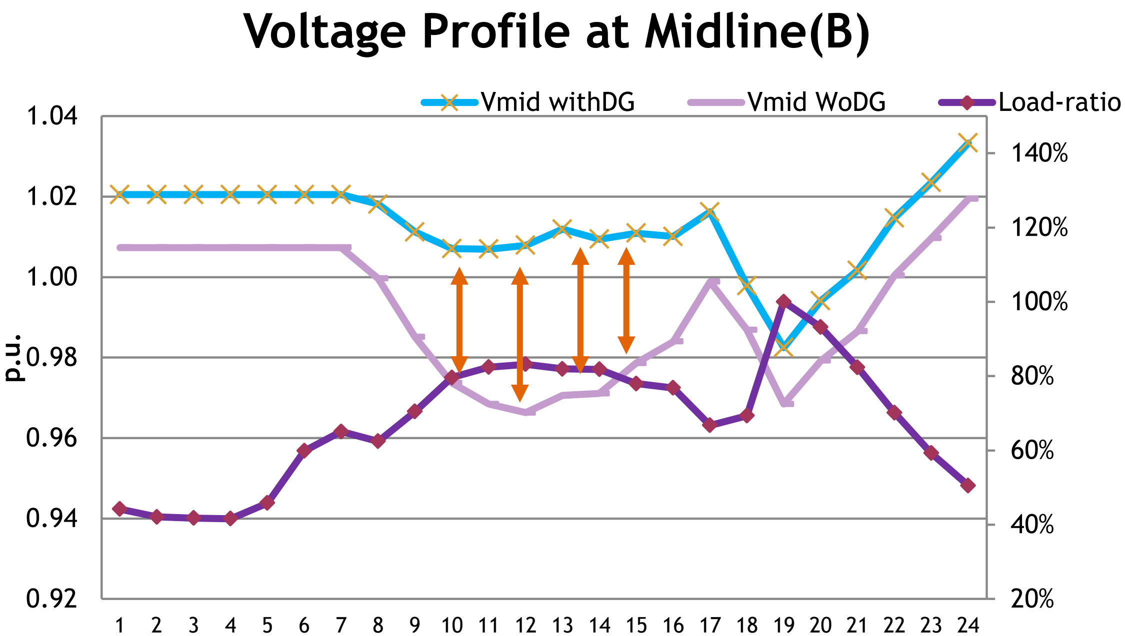


Figure 8 Result of voltage profile 24 hrs. at Midline (B)

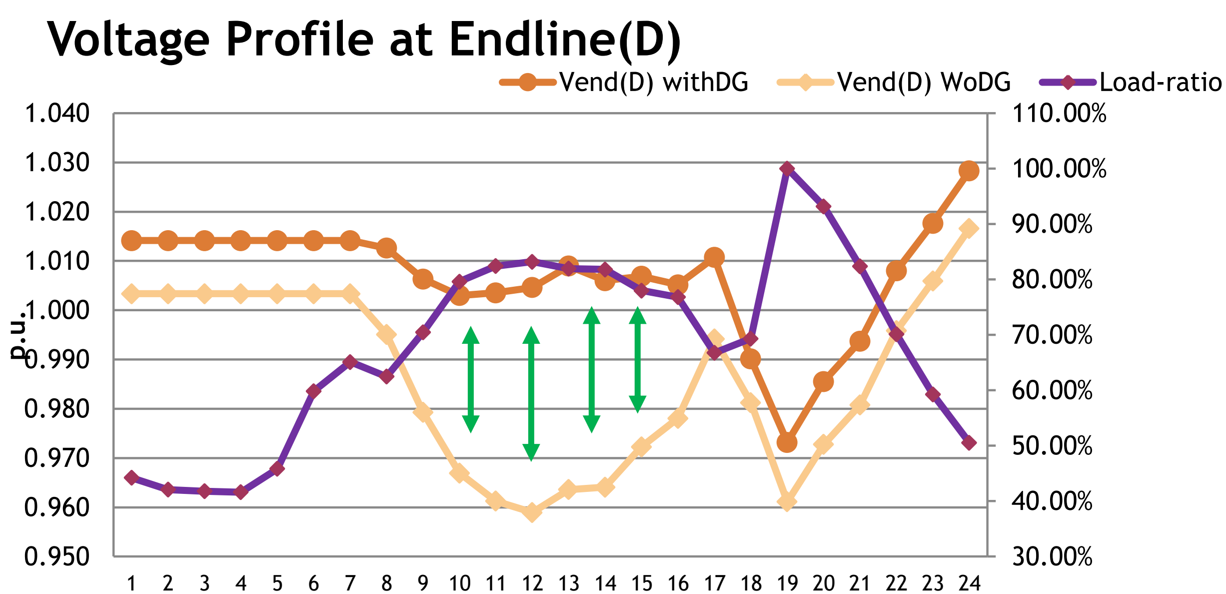


Figure 9 Result of voltage profile 24 hrs. at Endline (D)

VOLTAGE PROFILE VS DG RATIO

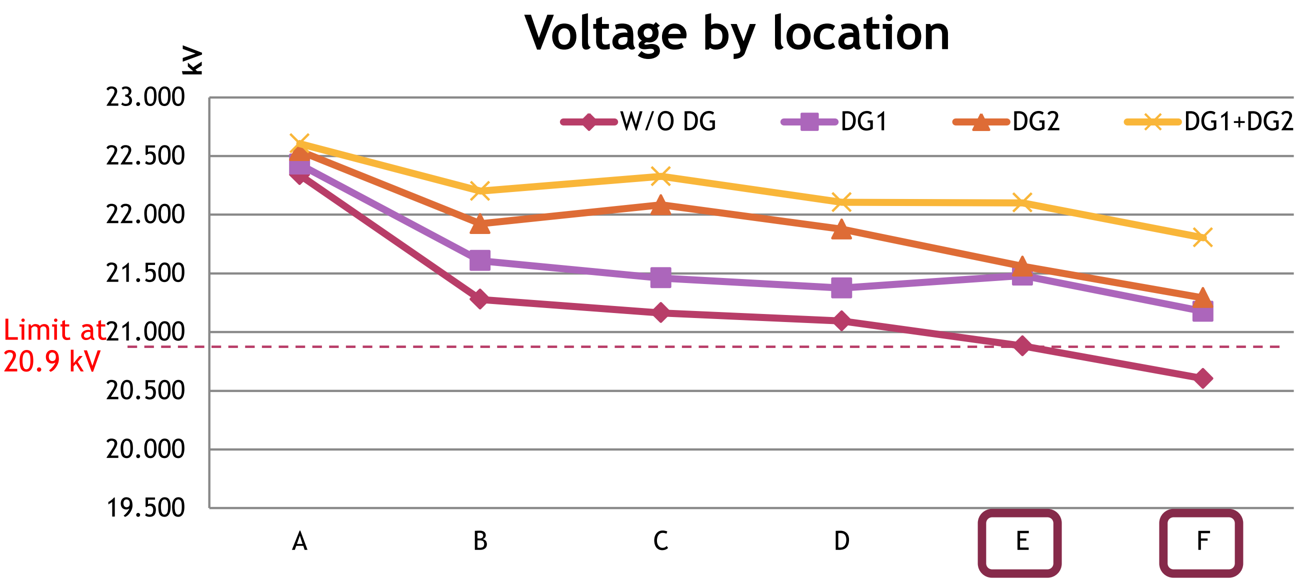


Figure 10 Result of voltage level at each location

At ‘E’ and ‘F’ end of line, voltage without DG was lower than limit of Voltage level (20.9 kV).
With support of DG the voltage level of ‘F’ rise from 20.6 kV to 21.8 kV.

	W/O DG	DG1	DG2	DG1+DG2
DG Ratio (DG/Load)	0	0.39	0.81	1.20

DG Ratio VS Voltage Rise %

Location		W/O DG	DG1	DG2	DG1+DG2
DG Ratio	DG/Load	0	0.4	0.8	1.2
○ Substation	A	22.339	0.40% (22.428)	0.91% (22.543)	1.20% (22.606)
○ Middle of line	B	21.278	1.55% (21.608)	3.03% (21.923)	4.34% (22.201)
○ DG2(PV 5.085MW)	C	21.164	1.40% (21.461)	4.35% (21.084)	5.50% (22.327)
○ EndlineDG2	D	21.094	1.33% (21.375)	3.71% (21.876)	4.80% (22.106)
○ DG1(Gen 2.414MW)	E	20.882	2.88% (21.483)	3.25% (21.560)	5.84% (22.102)
○ EndlineDG1	F	20.603	2.78% (21.176)	3.34% (21.291)	5.83% (21.804)

VOLTAGE RISE

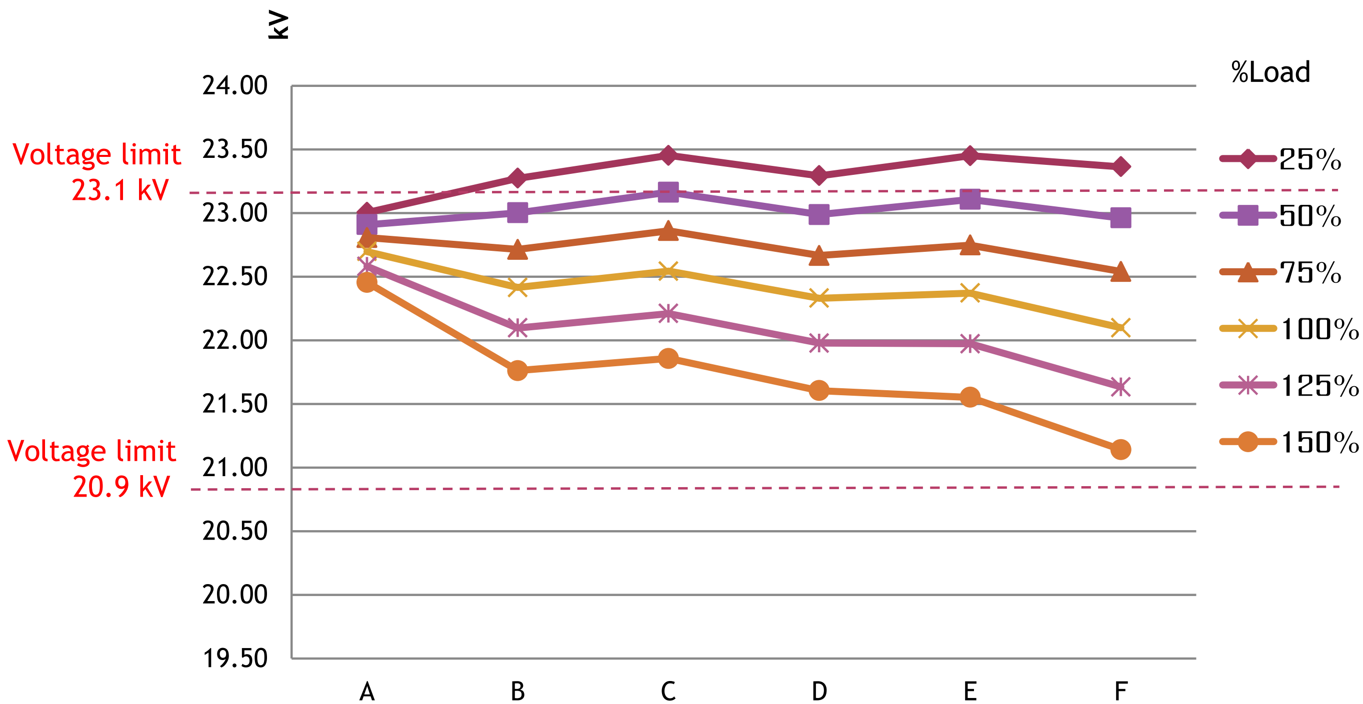


Figure 11 Result of voltage level with vary of load from 25% - 150%

DN with the support of voltage level by DG, voltage level in the range of grid code event the high load without under voltage problem at end of line. Weak network, max DG with min load, voltage rise may occur.

Effect on traditional improving under voltage level

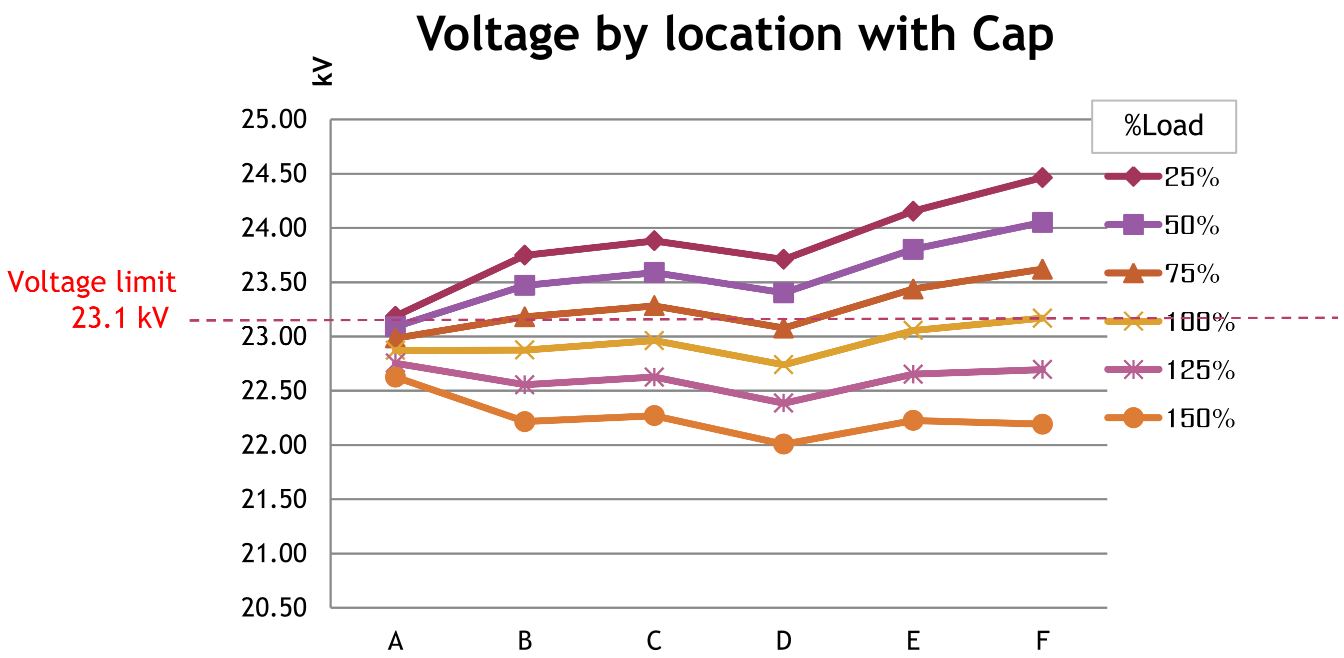


Figure 12 Result of voltage level with vary of load from 25% - 150% with support of switching capacitor installation.

Traditional improving under voltage level is install a shunt capacitor In the network. In this feeder, a 1500kVar shunt capacitor was used to improve the voltage level before installing of DG.
This important, when DG integrated to DN, the voltage level was raised. When switching shunt capacitor to DN, the Distribution operator should consider carefully with load level.

DG RATIO VS VOLTAGE RISE

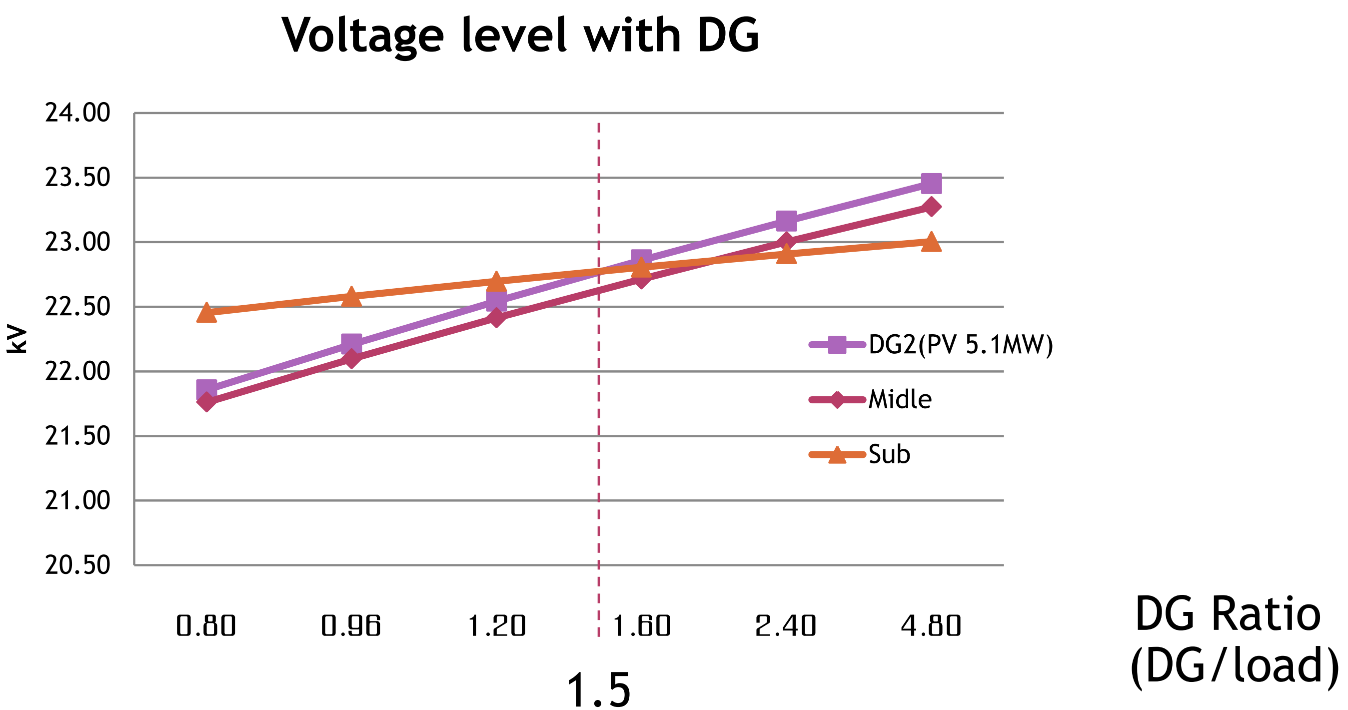


Figure 13 Result of voltage level with vary of DG Ratio

At DG Ratio higher than 1.5, voltage level along feeder inclined to be higher than voltage at substation. With DG smaller than load the voltage may be raised by effect of DG but not higher than at substation.

LOSS REDUCTION WITH DG

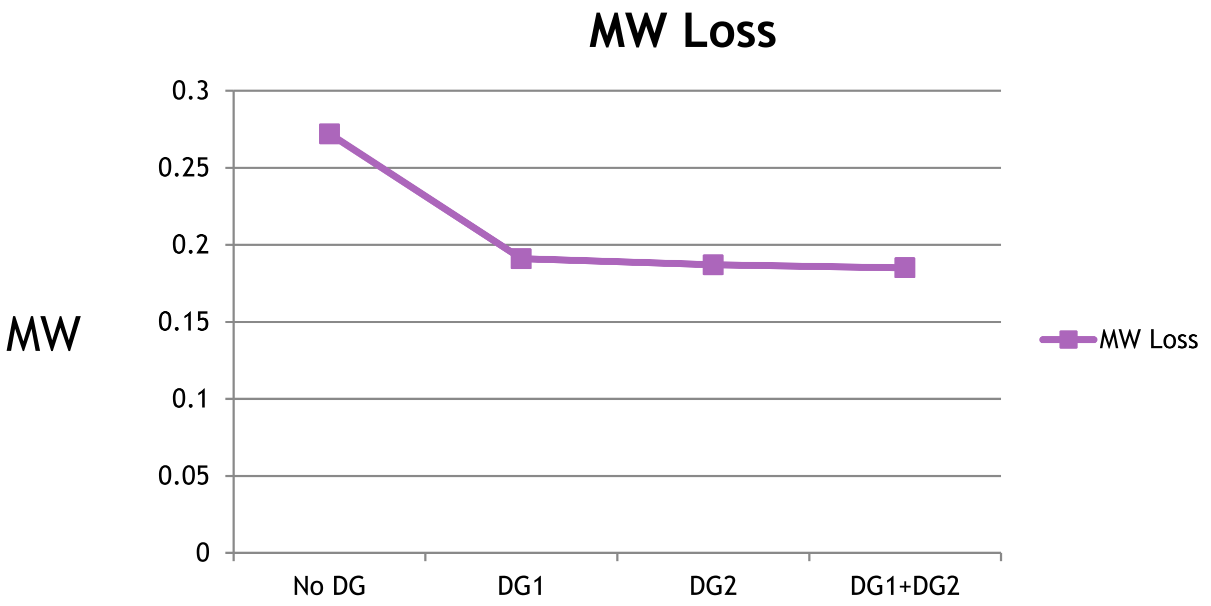


Figure 14 Result of Power Loss with vary of DG installation rating

In this case, with DG installation the power loss was less than without DG. Due to DG smaller than Load, the incorporation of DG into a radial distribution system could result in line loss reduction.

IMPACT OF DG TO LOSS

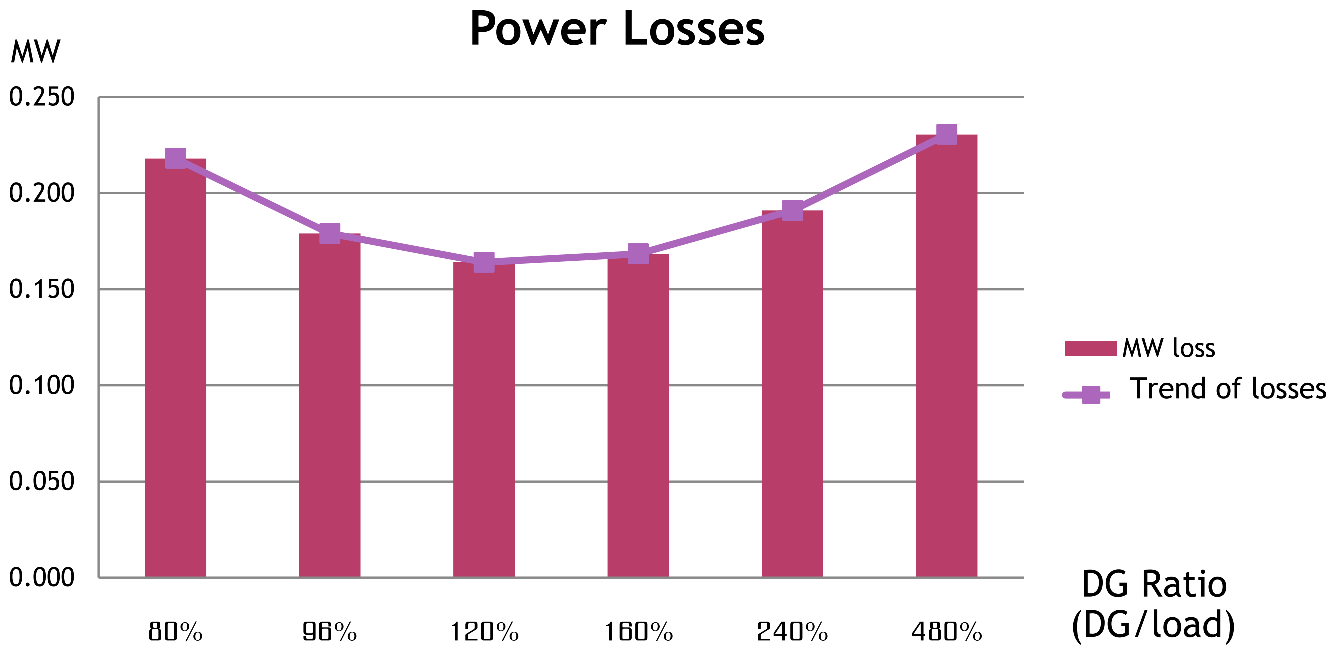


Figure 15 Result of Power Loss with vary of DG Ratio

When DG-ration increased beyond 1.5, loss essentially increases. This showed that the integration of DG into a radial distribution system may result in higher line loss if DG power rating and load were not properly related.

CONCLUSION

- DG could raise voltage level of Distribution Network.
- DG Ratio (DG/Load): the higher DG Ratio , the higher voltage rise % especially end of line.
- Weak network, maximum DG with minimum load, leaded to voltage rise problem.
- DG could reduce power loss with the proper generation rating.
- DG Ratio: the higher than 1.5, the increasing of power loss in the DN.

Thank you

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