# THE IMPACT OF SMALL SCALE EMBEDDED GENERATION AND EEDSM ON HISTORICALLY DESIGNED NETWORKS AND HOW IT WILL AFFECT NETWORKS OF FUTURE CITIES

**Presented by:**

**Jaco Alberts Pr Eng**

**7 October 2014**

# CONTENTS

- Background
- Typical planning and design parameters
- EEDSM impact
- SSEG impact
- Conclusion
- Questions

# BACKGROUND

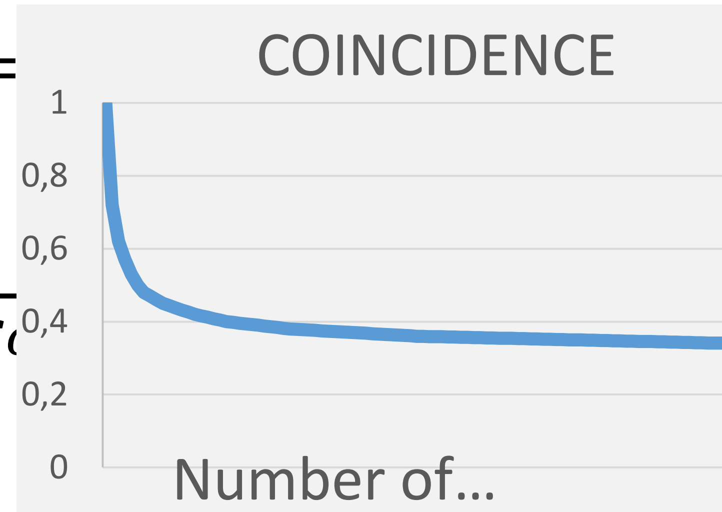
- Energy Efficiency, DSM, Renewables implemented on existing networks – are original design parameters revisited? Compliance?

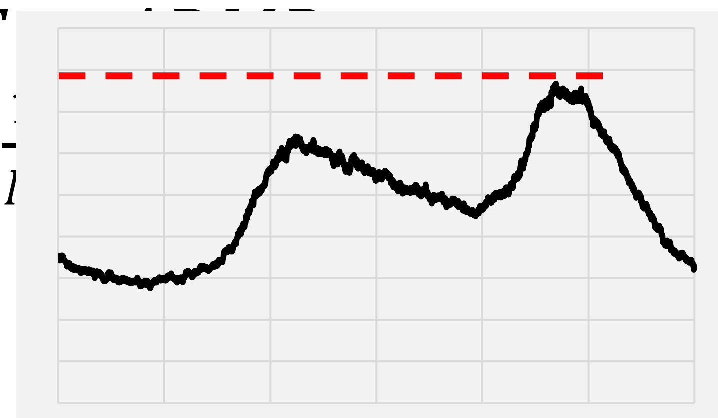
- Small scale embedded generators (SSEG): embedded in distribution network. National Network System Operator does not have control over them. Do Utilities know about each and every SSEG generator?

- SSEG typically uncontrolled from utility point of view.
  - Consumers do what they want.
  - Create safety problems (reverse power flow).
  - Do all grid connected SSEG's comply with requirements (RPP Grid Code; NRS 097-2-1; NRS097-2-2; NRS097-2-3)?

# DESIGN AND PLANNING PARAMETERS DETERMINISTIC METHODS

| | |
|---|---|
| **Coincidence; Diversity**<br><br>**MD= Max. demand** | $Coincidence =$ …<br><br>$Diversity = \frac{}{Co…}$ |
| **ADMD**<br>**(after diversity MD)**<br><br>**N=No of Consumers**<br>**DF = Diversity correction factor**<br>**k = Coincidence** | $MD = N \times DF$ …<br>$ADMD = \lim_{N \to \infty}$ …<br>$DF = 1 + \frac{k}{N}$ |



# DESIGN AND PLANNING PARAMETERS STATISTICAL METHODS

**Herman Beta method (NRS034):**

**ADMD (A) = μ**

**C = Circuit breaker size (A)**

$$p(x) = \frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha,\beta)} \qquad 0<x<1$$

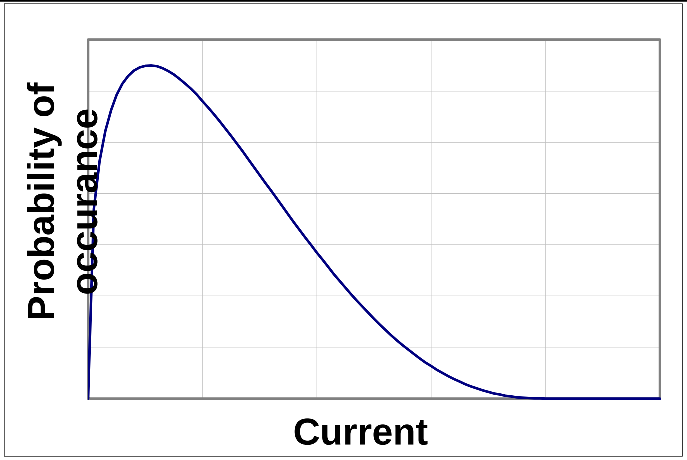
Where $B(\alpha,\beta) = \int_0^1 u^{\alpha-1}(1-u)^{\beta-1}du$

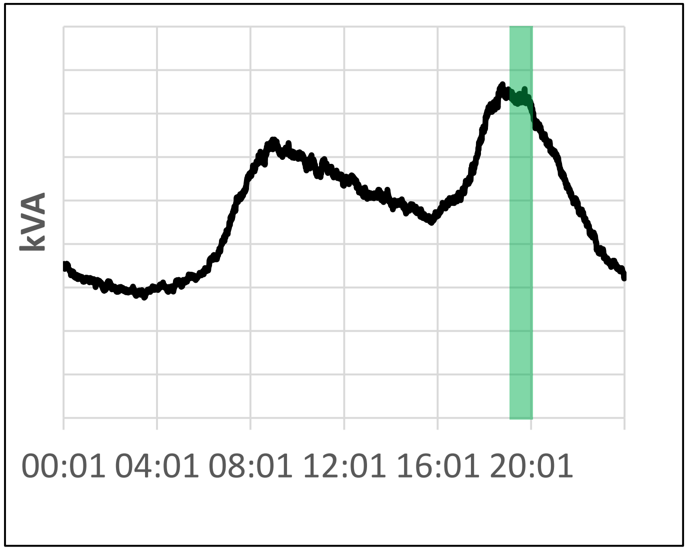
$$\alpha = \frac{\mu(c\mu - \mu^2 - \sigma^2)}{c\sigma^2}$$

$$\beta = \frac{(c-\mu)(c\mu - \mu^2 - \sigma^2)}{c\sigma^2}$$

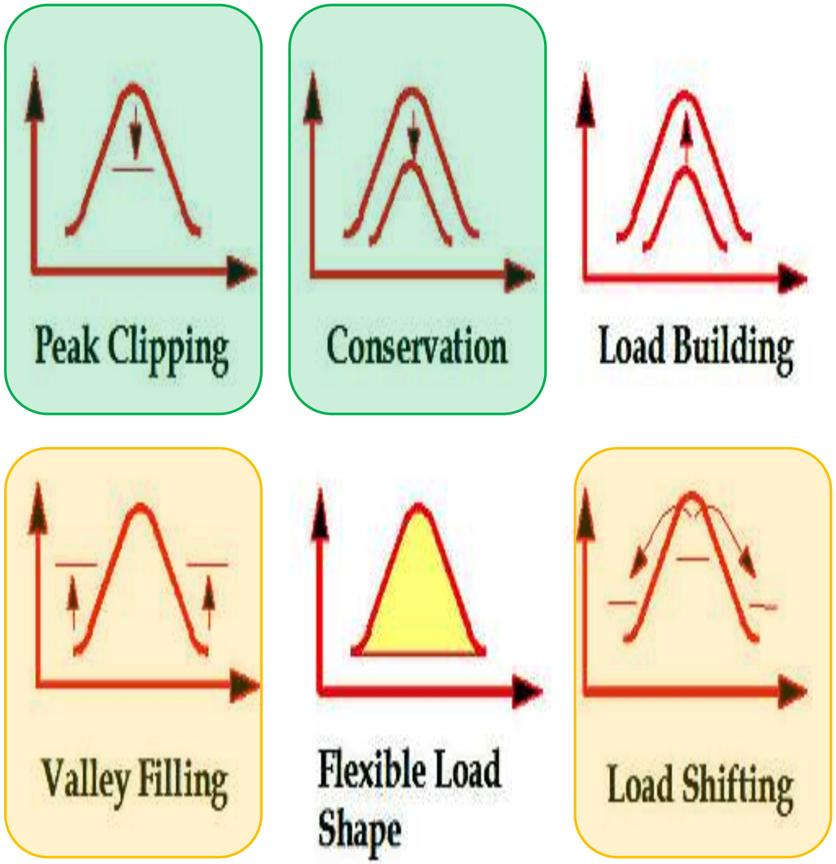
$$\mu = c\frac{\alpha}{\alpha+\beta}$$

$$\sigma^2 = c^2 \cdot \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)}$$



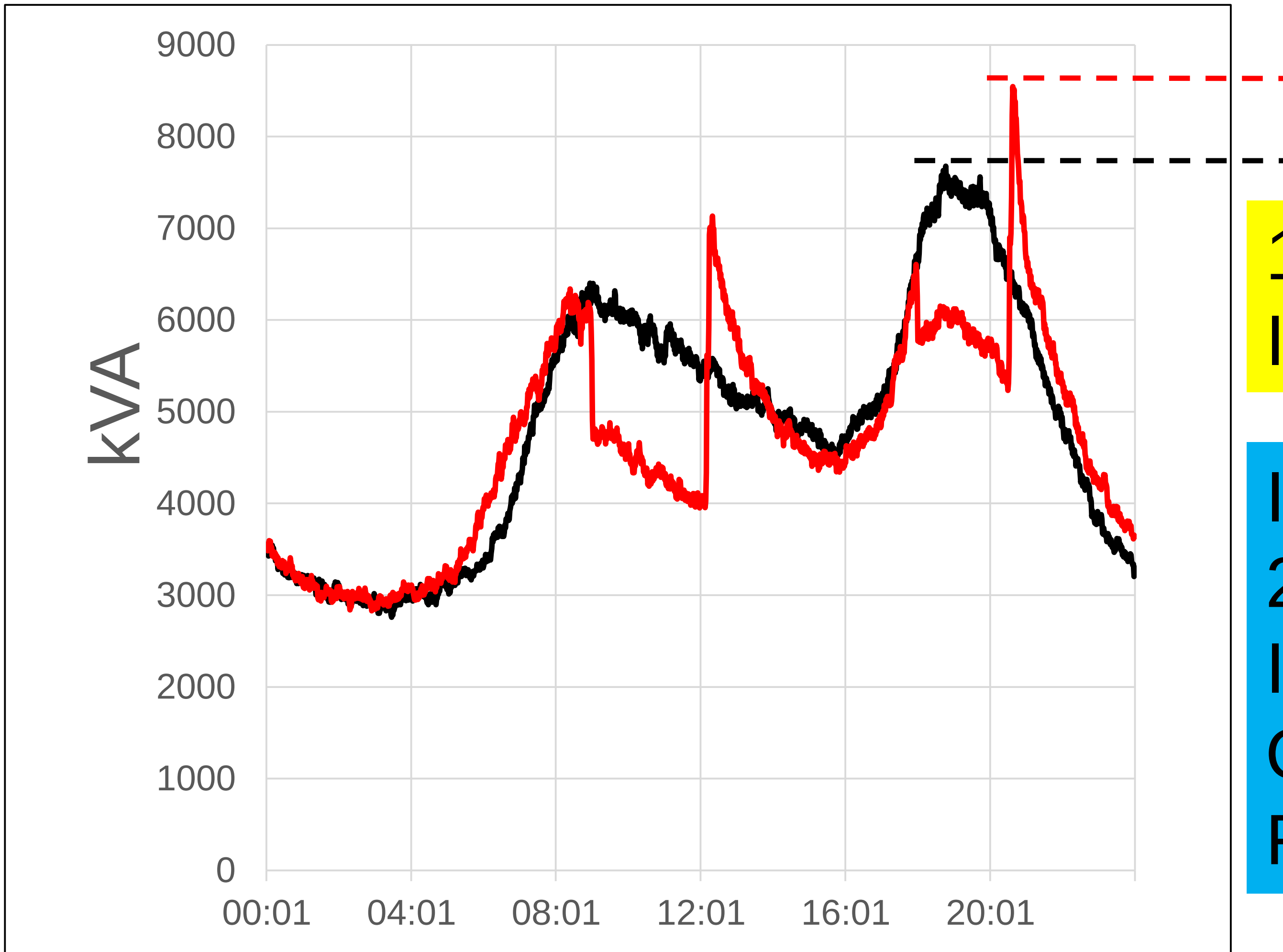
# EEDSM




ENERGY EFFICIENCY

DEMAND SIDE MANAGEMENT

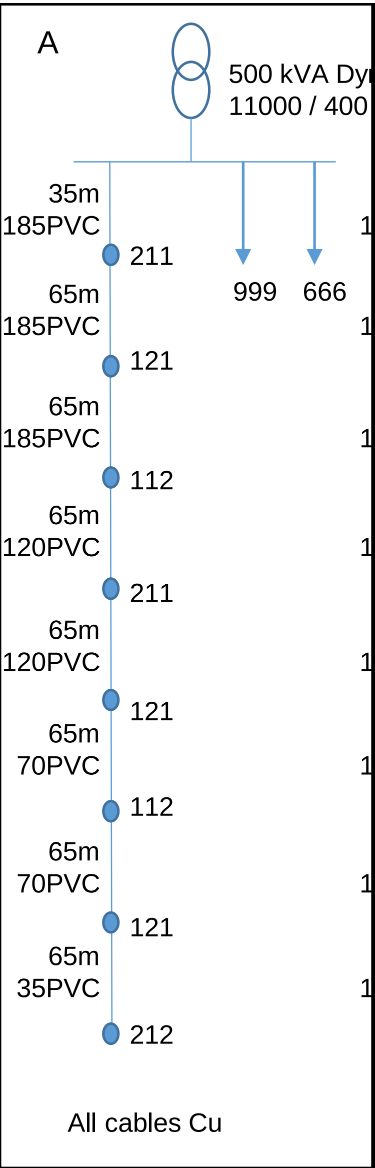
# EXAMPLE: ADMD IMPACT OF RIPPLE CONTROL (DSM INITIATIVE)

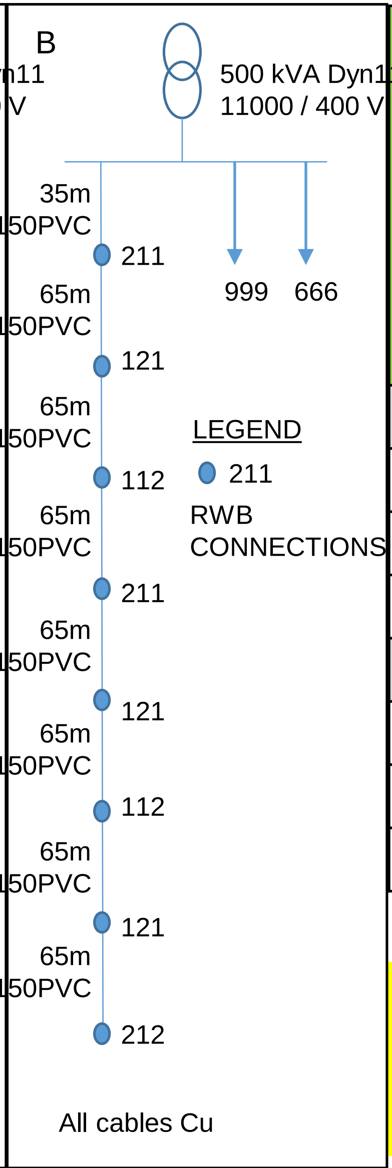



11.6% INCREASE

ITALY: 25% INCREASE ON ADMD IN FORMULAE

# RIPPLE CONTROL EXAMPLE LOAD FLOW



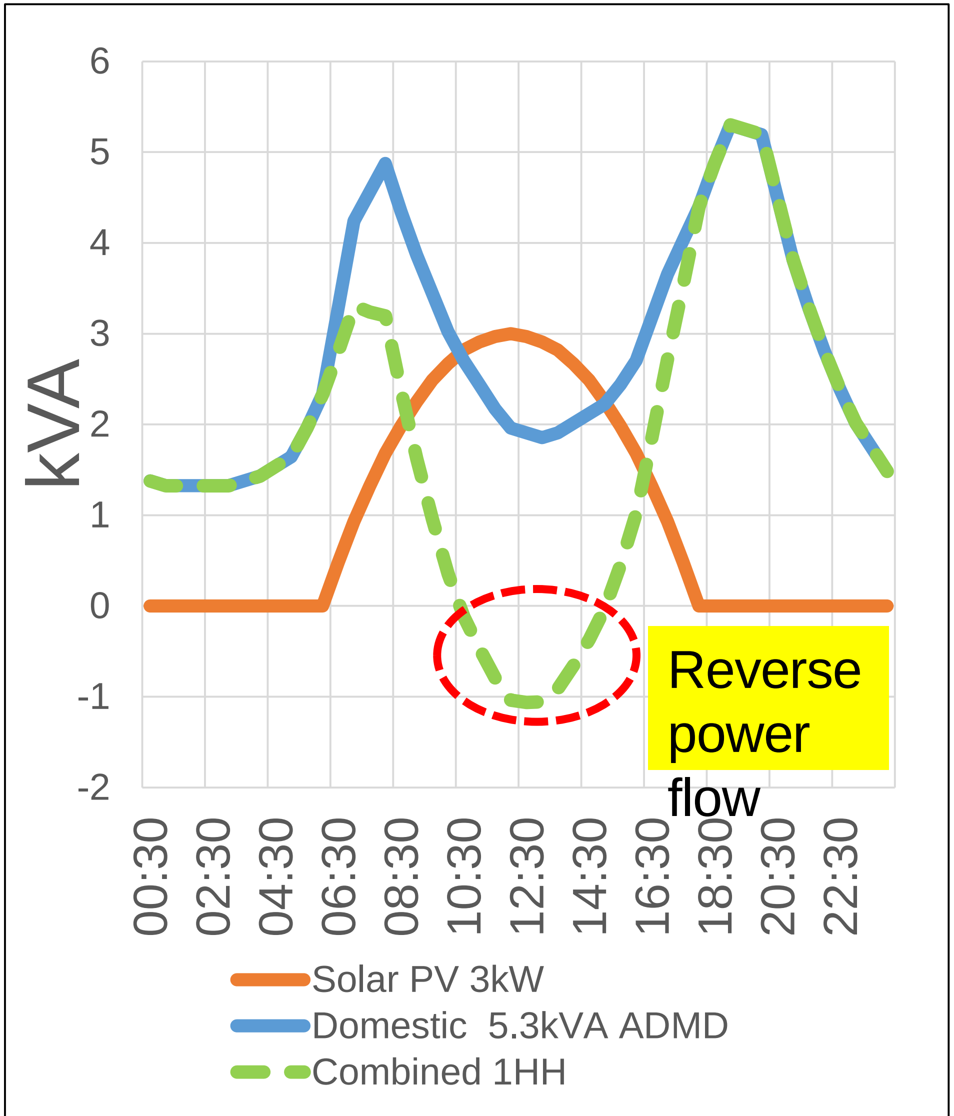

| ADMD (kVA) | Trf load (kVA) | Min $V_{nom}$ (%) | Cable load (% of rated current) | % LV reach @ 90% $V_{nom}$ |
|---|---|---|---|---|
| **Tapered LV cable feeder (A)** | | | | |
| 5.3 design | 478 | 90.14 | 77 | 100 |
| 5.8 (11.6%) | 519 | 89.28 | 84 | 73 |
| 6.25 (25%) | 560 | 88.44 | 91 | 60 |
| **One size LV cable feeder (B)** | | | | |
| 5.3 design | 478 | 91.34 | 88 | 100 |
| 5.8 (11.6%) | 519 | 90.59 | 96 | 100 |
| 6.25 (25%) | 560 | 89.85 | 104 | 85 |

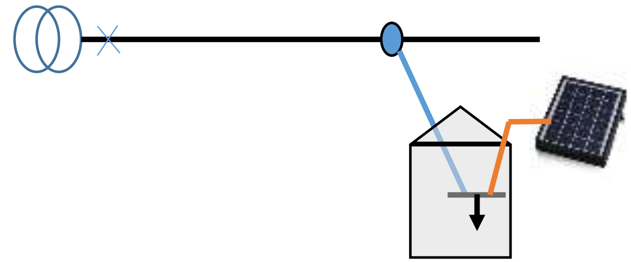
**5 kVA present avg. demand per consumer.**
**Designed 5.3 kVA ADMD**
**5 kVA + 11.6% = 5.8 kVA; 5 kVA + 25% = 6.25 kVA**

# RIPPLE CONTROL LOAD FLOW OBSERVATIONS

- Increase in ADMD will change Herman-Beta volt drop method parameters.
- Increased ADMD resulted in volt drop exceeding limits (90% p.u. at consumer distribution board)
- Tapered LV feeders are at greater risk
- Transformer overload within overload specifications of transformers
- Single size LV feeder overload occurred for section close to transformer.

# SMALL SCALE EMBEDDED GENERATION
# SOLAR PV



Typical residential profile:

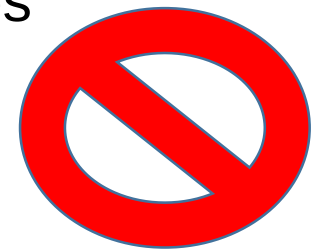
- Averaged consumer profile 5.3kVA ADMD
- Individual profile shape of course different
- 3kW PV at unity power factor
- Potential surplus energy at low demand conditions

# SSEG STUDY EXCLUSIONS

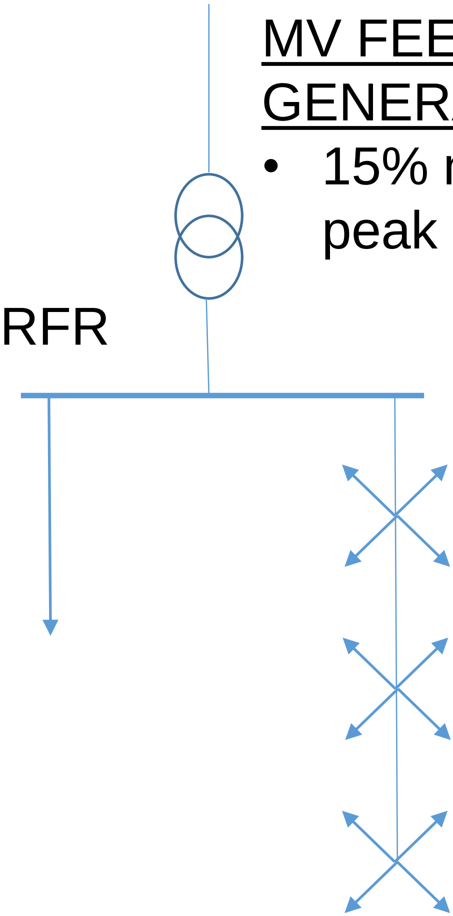
- Considered only PV. Micro wind and other forms of SSEG excluded

- Considering only class A1 (<13.8kVA, i.e. 60A single phase), as defined in the RSA RPP Grid Code.

- Solar PV related issues excluded from this paper:
  - safety related issues
  - metering, tariff, billing and revenue related issues
  - protection & fault level studies
  - power factor impact
  - technical losses
  - Grid tie inverter specifications and capabilities



# NRS 097: MAX EMBEDDED GENERATION ALLOWED



MV FEEDER GENERATORS:

- 15% max of feeder peak load

TOTAL LV GENERATION:

- 75% max of TRFR rating

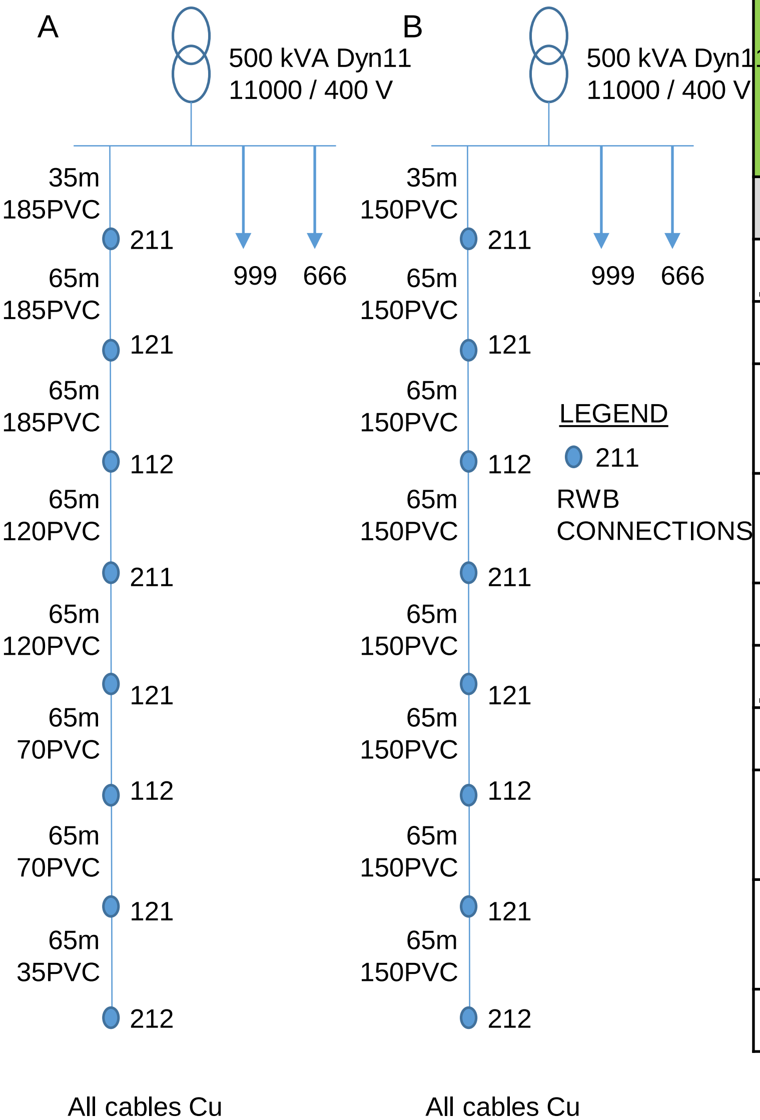
SHARED LV FEEDER CONSUMER GENERATORS:

- Max 25% of consumer NMD
- Total shared: max 25% of TRFR rating
- >4.6kVA: Balanced 3ph
- Max individual limit: 20kVA

DEDICATED LV FEEDER CONSUMER GENERATORS:

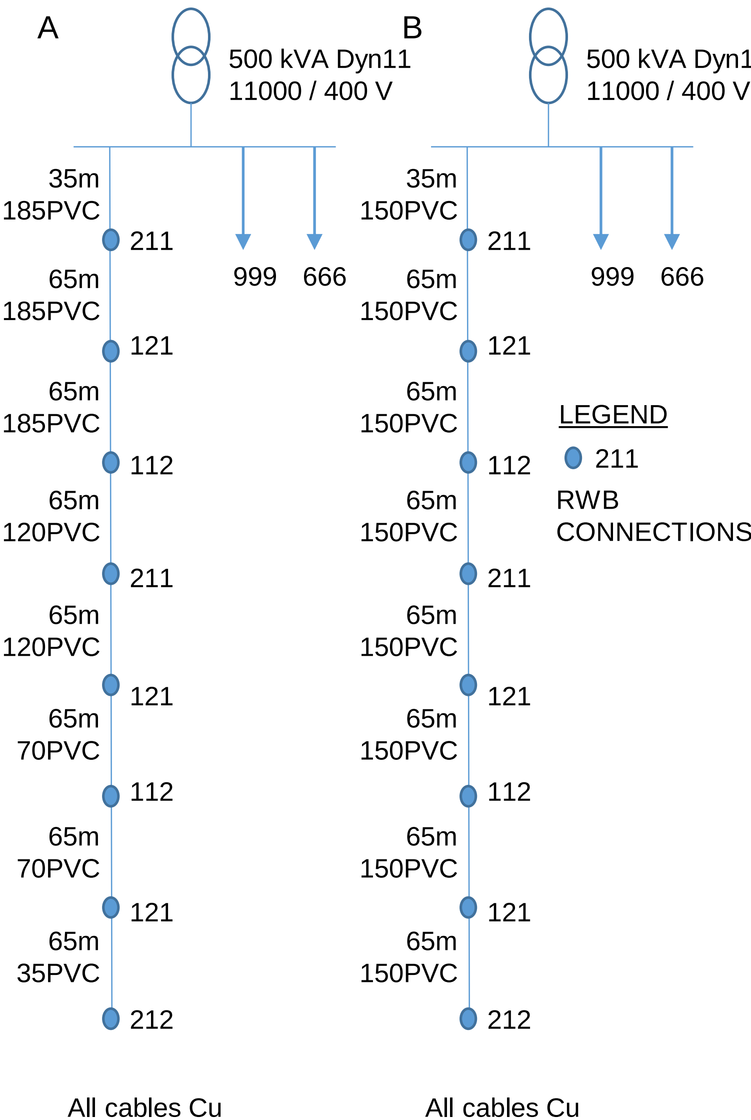
- Max 75% of consumer NMD
- Max 1ph: 13.8kVA
- >4.6kVA: Balanced 3ph

# SSEG EXAMPLE LOAD FLOW STUDY RESULTS – 3kW PV




| Scenario | Trf load (kVA) | Min V % | Max V % |
|---|---|---|---|
| **3kW solar PV embedded generator systems** | | | |
| **Tapered LV feeder (A):** | | | |
| No generator connected | 150 | 101.40 | 103.42 |
| 25% penetration close to transformer | 90 | 101.60 | 103.56 |
| 25% penetration at end of feeder | 90 | 102.02 | 103.76 |
| 100% penetration | -68 | 103.67 | 105.33 |
| **One size LV feeder (B):** | | | |
| No generator connected | 150 | 101.64 | 103.42 |
| 25% penetration close to transformer | 90 | 101.85 | 103.56 |
| 25% penetration at end of feeder | 90 | 102.12 | 103.58 |
| 100% penetration | -77 | 103.68 | 105.23 |

# SSEG EXAMPLE LOAD FLOW STUDY RESULTS – 9kW PV

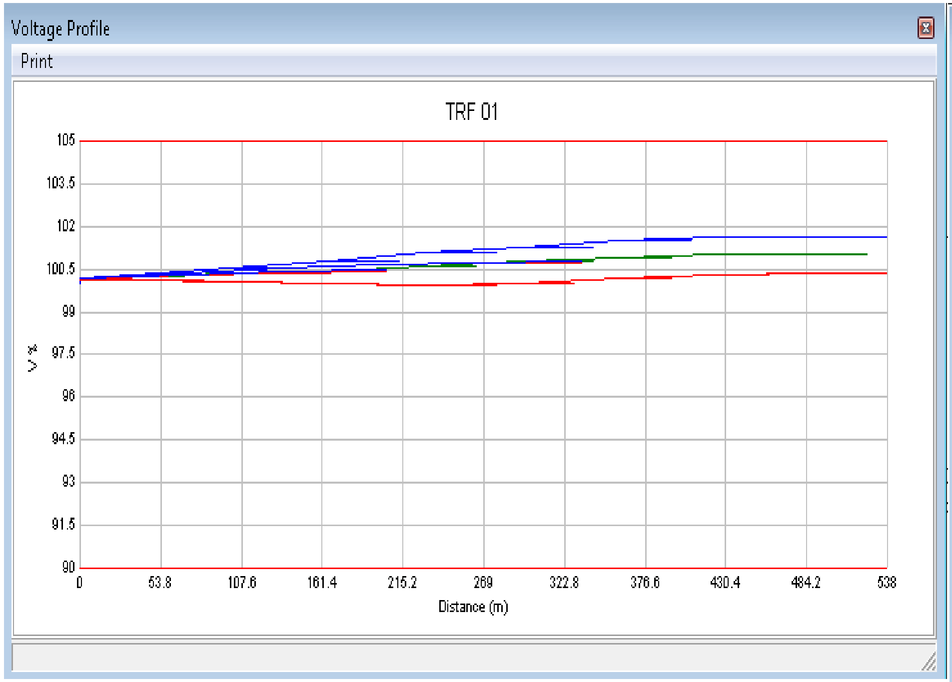


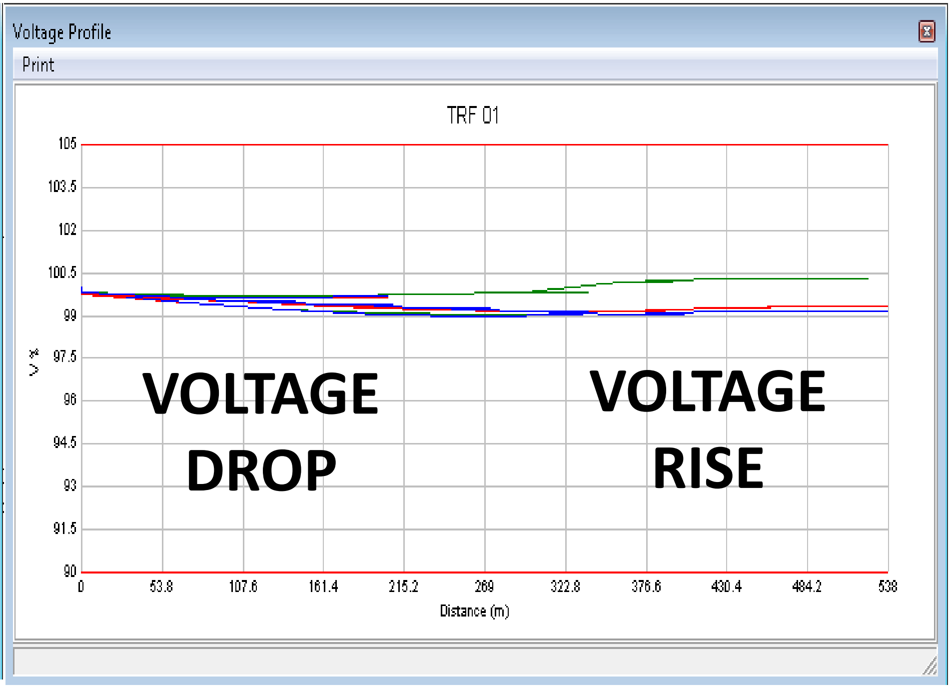

| Scenario | Trf load (kVA) | Min V % | Max V % |
|---|---|---|---|
| **9kW solar PV embedded generator systems** | | | |
| **Tapered LV feeder:** | | | |
| No generator connected | 150 | 101.40 | 103.42 |
| 25% penetration close to transformer | 42 | 101.82 | 103.90 |
| 25% penetration at end of feeder | 42 | 102.95 | 107.34 |
| 100% penetration | -247 | 104.15 | 111.96 |
| **One size LV feeder:** | | | |
| No generator connected | 150 | 101.64 | 103.42 |
| 25% penetration close to transformer | 42 | 102.09 | 103.95 |
| 25% penetration at end of feeder | 42 | 102.93 | 106.48 |
| 100% penetration | -255 | 104.17 | 111.26 |

# ILLUSTRATING VOLTAGE RISE FOR LV SSEG SYSTEMS

100% SSEG penetration 3kW systems

25% SSEG penetration 3kW systems – at end of feeder



# SSEG LOAD FLOW OBSERVATIONS

- Voltage rise:
  - Will be worse when voltage boost exists, e.g. 415V and 420V transformer secondary voltage at nominal tap.
  - Voltage regulation relative to Declared Nominal Voltage (400V three phase, 230V single phase)
  - MV/LV Transformers usually have fixed taps.

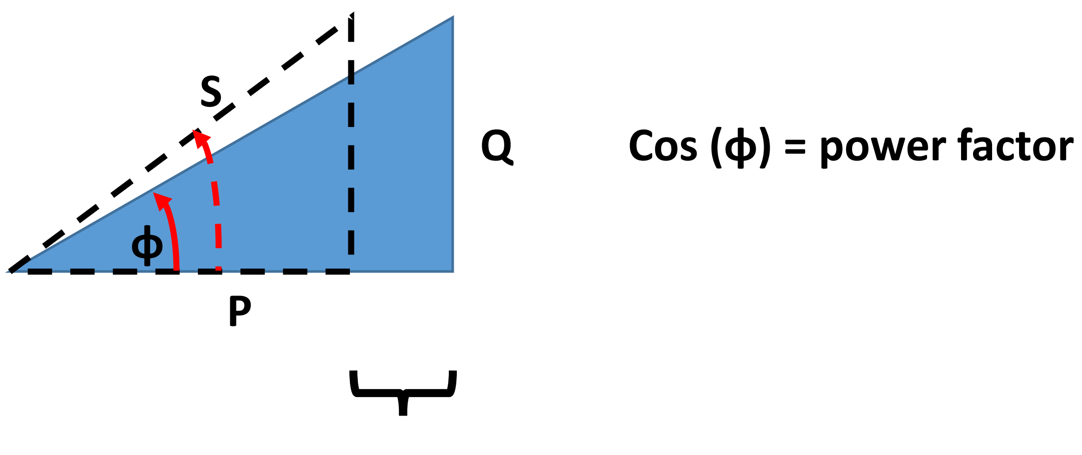
- Reverse flow of energy across transformer into MV network

- Although no cables were overloaded in these examples, increasing the amount each house can inject under low load conditions, e.g. to 60A, will result in conductor overload. Important to maintain designed network diversity

# OTHER OBSERVATIONS FOR FURTHER STUDY

- Fault level increases as generators are added. Traditionally, the fault level decreased downstream for the same voltage level. Are cables and equipment still adequately rated for faults?

- Power factor worsens (injecting only kW, not kVAr).



# CONCLUSION

- DSM measures implemented, e.g. ripple control, changed design parameters, however network designs have never been revisited.
- SSEG can reduce the network's demand on grid power
- However, there is a risk of voltage rise beyond regulation limits, especially close to the transformer if not "controlled"
- Potential loss of design diversity during low load conditions under reverse power flow conditions

END

THANK YOU

QUESTIONS?