



Impact of SSEG on SA MV networks

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Overview

- Objective of study
- Simulation Model and Assumptions
- Impacts on Voltage Regulation
- Impacts on Power Flow
- Harmonic Impacts
- Impacts on Energy Sold (Revenue)
- Conclusions
- Acknowledgments



Objective of Study

- The objective is to determine the technical and possible revenue impacts of SSEG installations, in commercial and industrial clients, on MV networks.
- During the DANIDA municipal capacity building project, the common questions with all municipalities involved were:
 - What is going to happen to our network once SSEG levels increase?
 - Revenue Impacts?

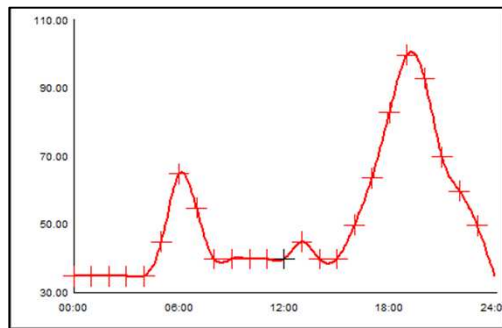
Simulation Model

- **Laboria** network customer base consists of;
 - 58% industrial customers
 - 32% residential customers
 - 10% light commercial customers
 - Total installed MV/LV transformers capacity of 33200kVA
 - All industrial clients are on dedicated MV/LV transformers, with residential and commercial customers on shared LV feeders
 - Feeders are operated as ring feeders
- **Flora Park** network customer base consists of;
 - 87% residential customers
 - 13% light commercial customers
 - Total installed MV/LV transformer capacity of 13 225kVA
 - All customers are on a shared LV feeder supply
 - Feeders are operated radially

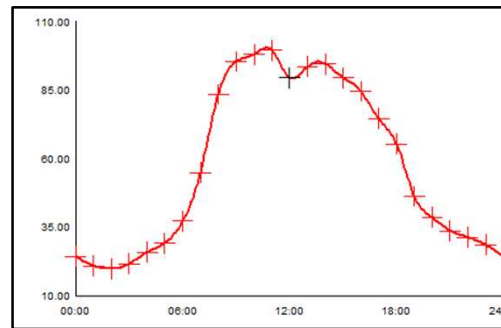


Load and generation Profiles

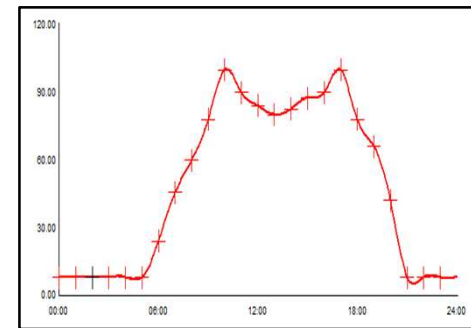
- Typical load profiles were setup



Residential



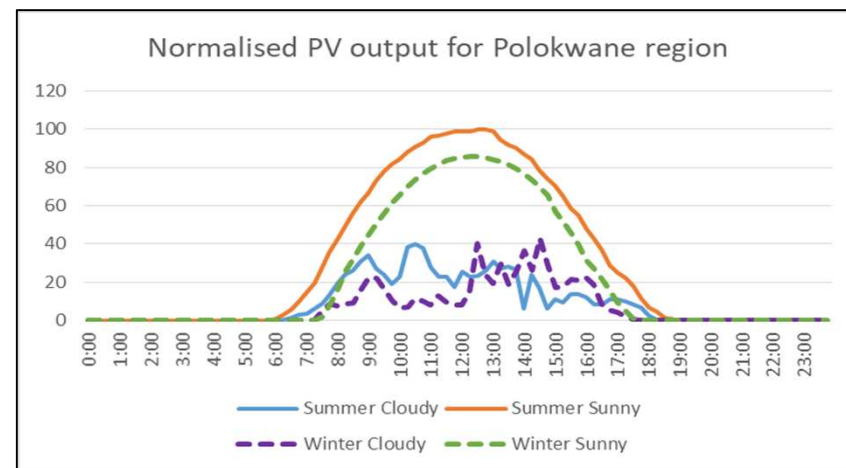
Commercial



Industrial

- PV generation profile was based on actual measured PV output from site in Polokwane

- Peak PV output achieved in summer with winter peak output about 80% of summer output.



Loading Assumptions

- It is assumed that the MV/LV transformers can load up to 100% of its installed capacity.
- Since studies are conducted considering the time of day, no diversity is applied to the transformer loading and loading is based on the customer load profile connected to that transformer.
- The following further assumptions were made w.r.t. loading in the chosen networks;
 - Peak load occurs in winter
 - Summer peak load is 80% of winter peak load
 - Minimum load peak occurs in summer and is equal to 25% of peak winter load (mid December to mid January due to industry shutdown, holidays)

Sizing of SSEG Installations

- NRS connection criteria is applied based on shared or dedicated LV feeder connection.
- All industrial clients have dedicated MV/LV transformers can install up to 75% of MV/LV transformer capacity in SSEG.
- Residential customers are connected using a 60A connection breaker (maximum demand = 13.8kVA). These customers limited to 25% of the total MD, i.e. max SSEG = 3.45kVA (3.45kW).
- All commercial customers are also on shared LV feeders hence will also be limited to maximum SSEG installation size of 3.45kVA (3.45kW).
- NRS also stipulates in the simplified criteria that the embedded generation should be limited to less than or equal to 15% of the MV feeder peak. Since there is no active monitoring of the MV feeder peak, to apply this criteria is not possible. As such it is not considered in the studies.

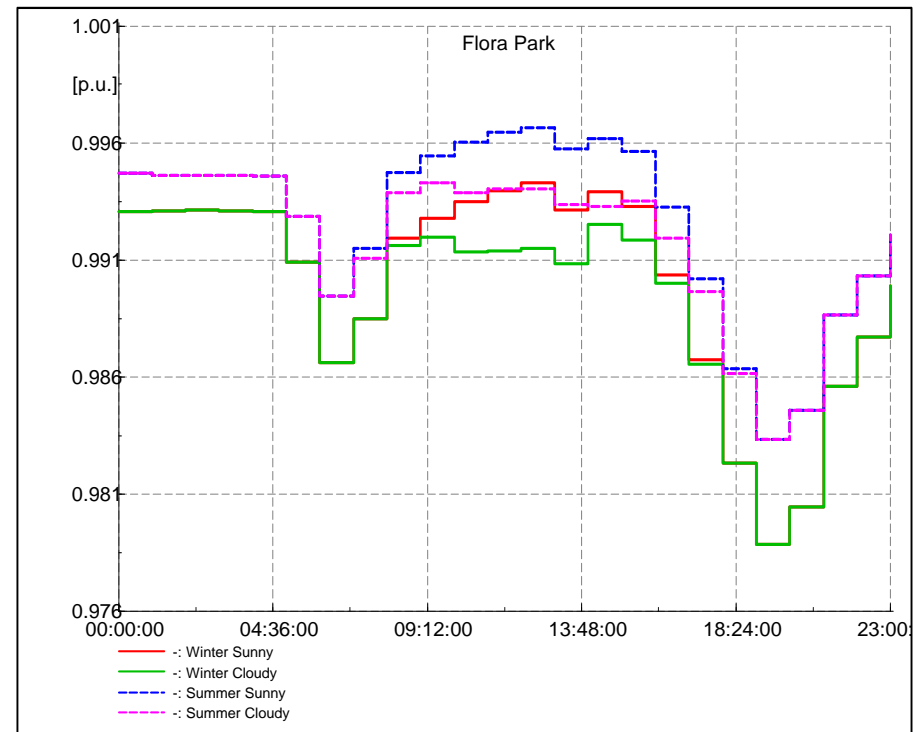
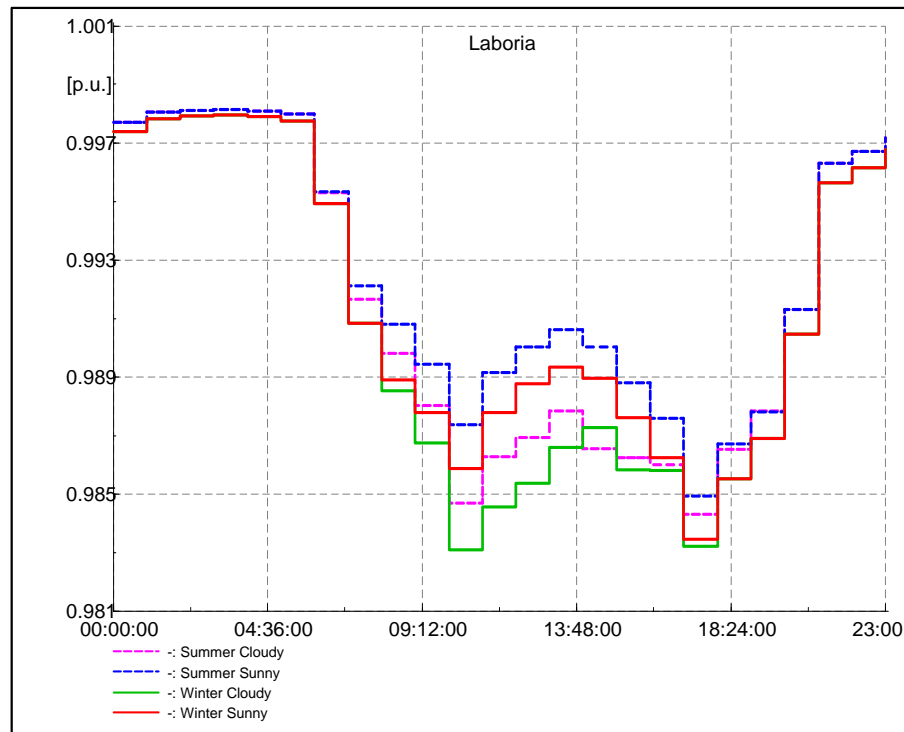
SSEG Assumptions

- SSEG penetration levels are considered as follows;
 - All clients are assumed to have SSEG installed on site and the installed size is the maximum allowable size
 - 0% penetration means no SSEG is generating power regardless of the time of day
 - 100% penetration means that every customer has SSEG installation and all SSEG installations is generating power up to a maximum allowed by the PV generation profile
 - For SSEG penetration levels between 0 and 100%, the generation at each of the customer's SSEG installation is limited to the specified percentage and also limited to the maximum allowed by the PV generation profile, **no stochastic scattering of generation in the LV networks is considered**

Study Criteria

- Since the load and PV generation varies, studies had to consider combinations of the following criteria;
 - Peak and minimum network loading
 - Sunny and cloudy days
 - Winter and summer loading
 - Varied levels of SSEG penetration
- Studies were conducted considering a 24 hour period in the respective season
- No variation for day of the week was considered

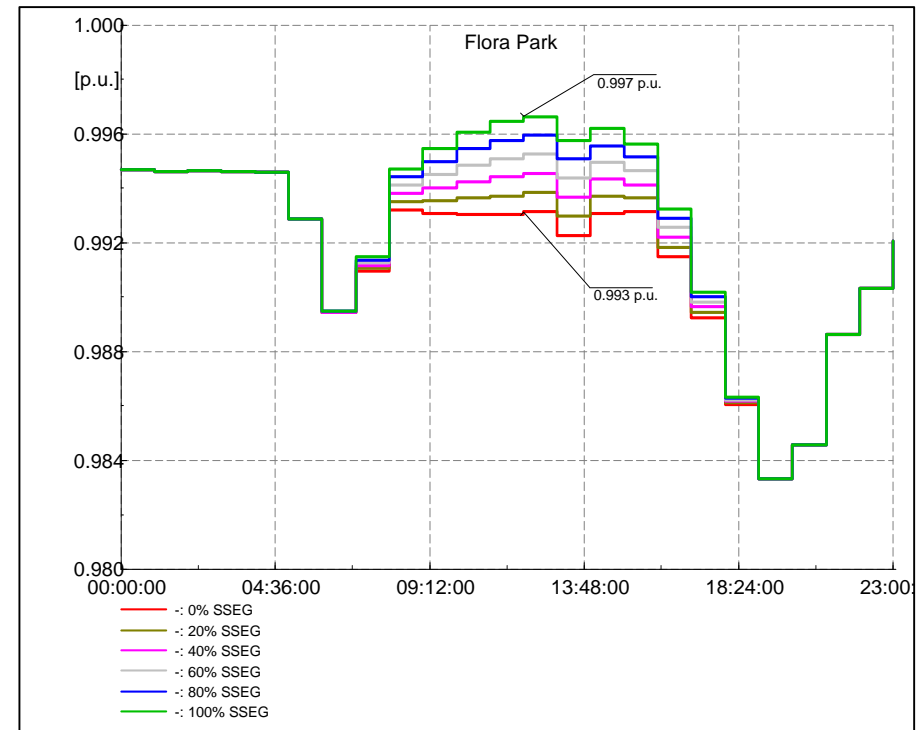
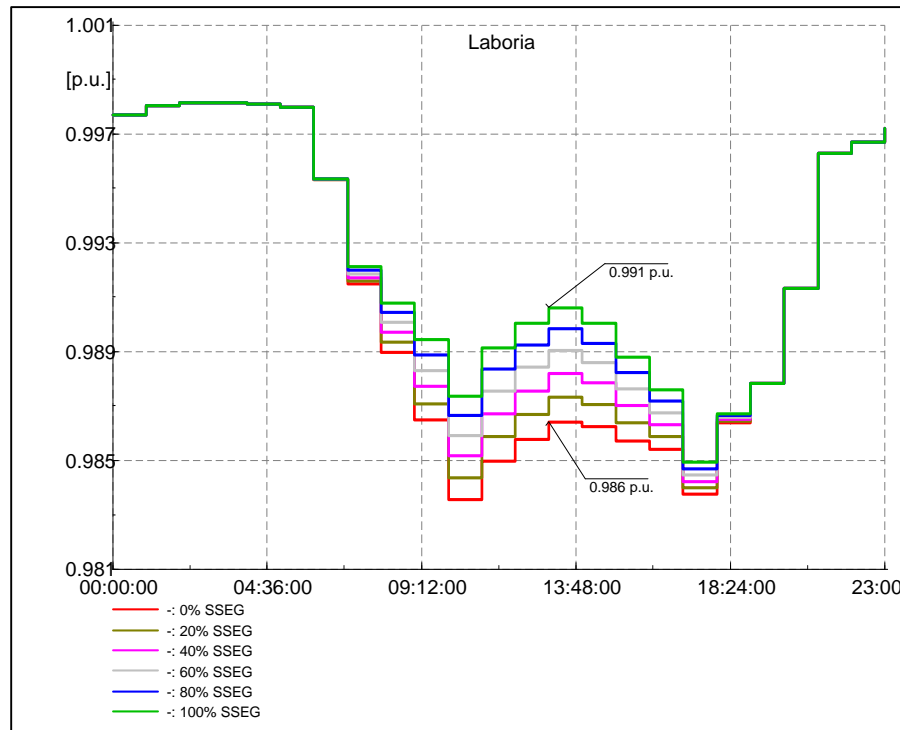
Voltage Impacts – Peak Loading Cloudy vs Sunny Day



- 100% SSEG
- Summer and Winter peak loading considered
- Voltage variation <1% between cloudy and sunny days for both winter and summer



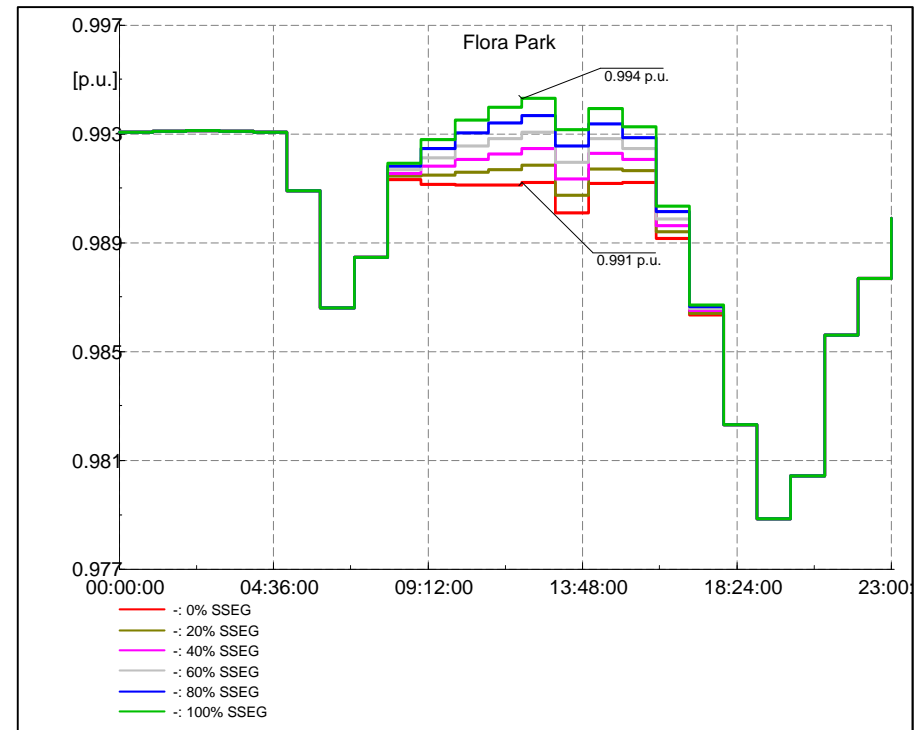
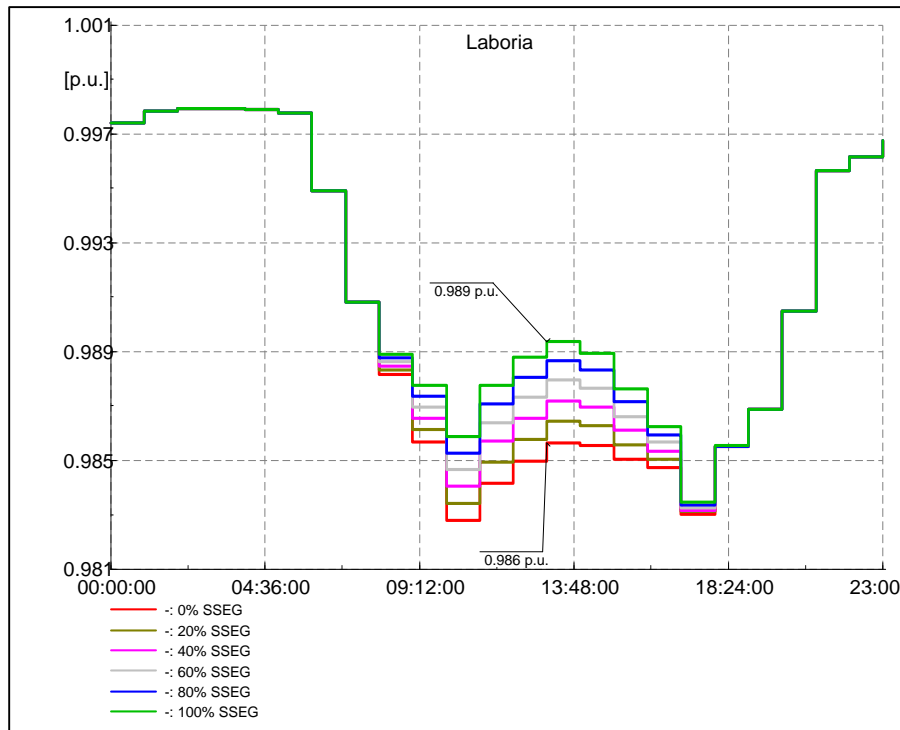
Voltage Impacts – Peak Loading Summer – Varied SSEG Levels



- 0 to 100% SSEG
- Summer peak loading considered
- Voltage variation <1% between 0% and 100%



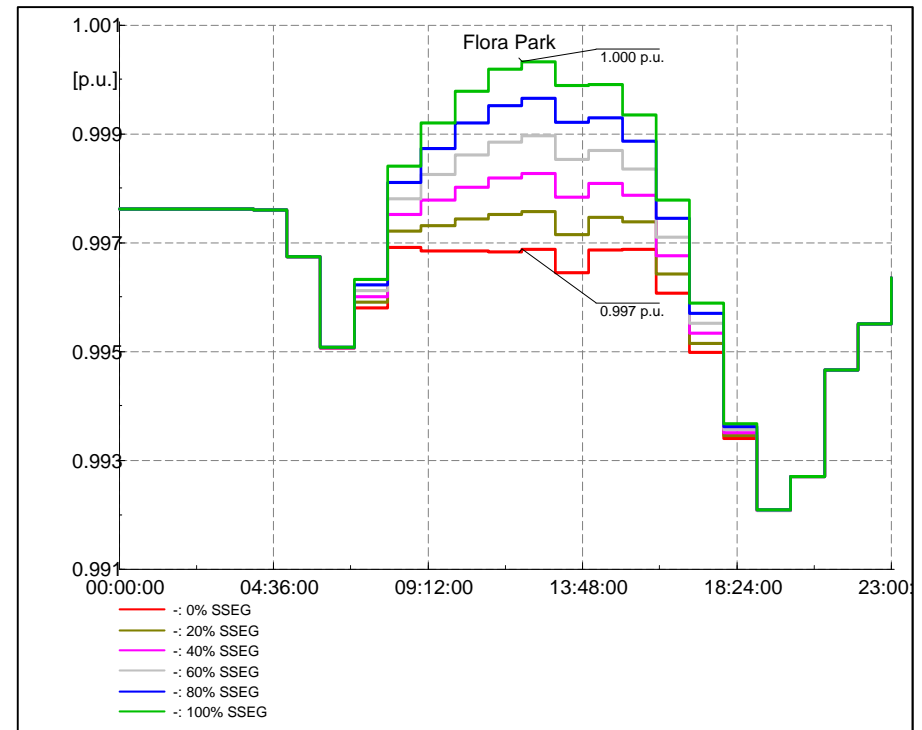
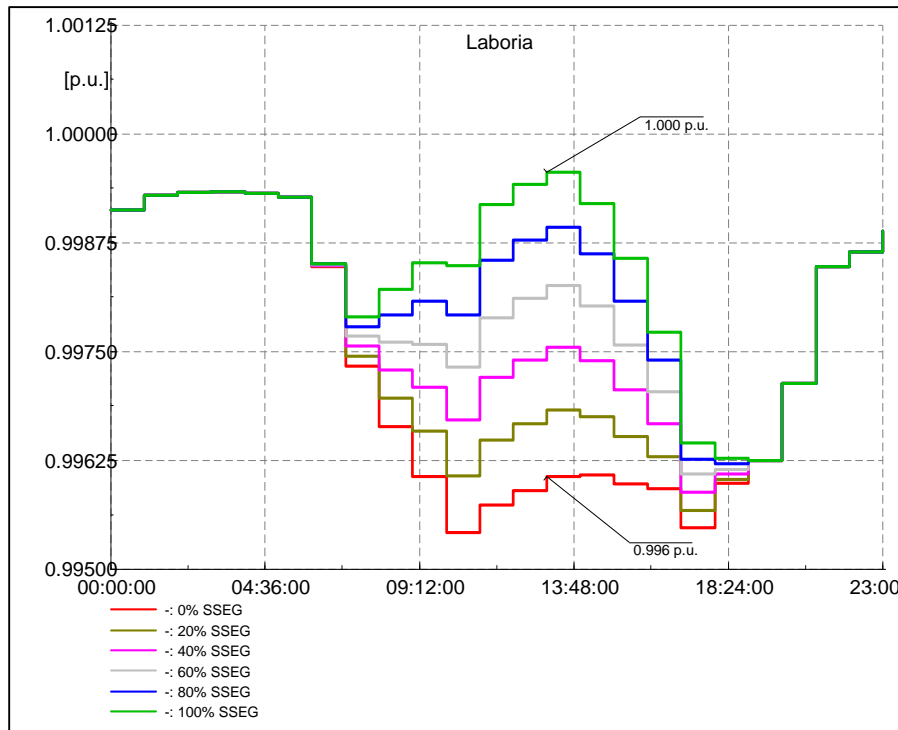
Voltage Impacts – Peak Loading Winter– Varied SSEG Levels



- 0- 100% SSEG
- Winter peak loading considered
- Voltage variation <1% between 0% and 100%



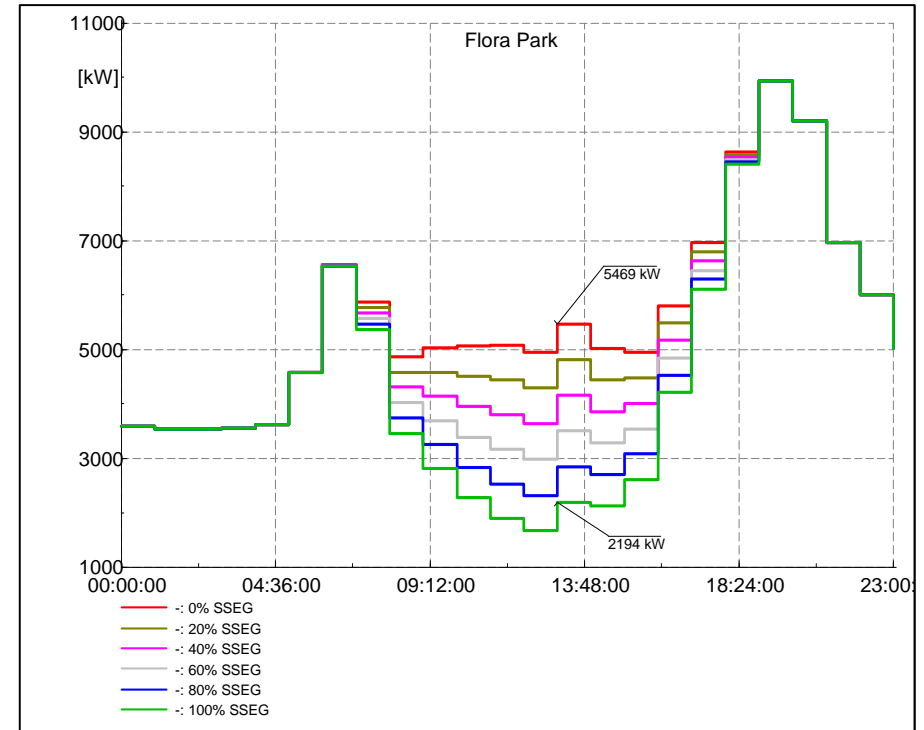
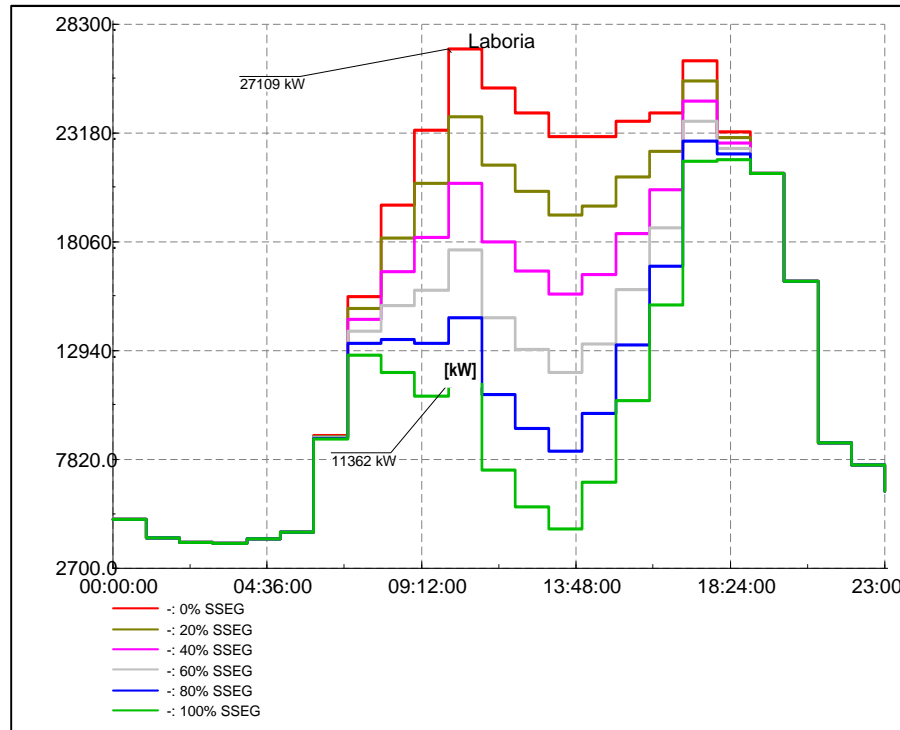
Voltage Impacts – Minimum Loading Summer– Varied SSEG Levels



- 0- 100% SSEG
- Minimum loading considered
- Lowest network loading experienced between mid December to mid January
- Voltage variation <1% between 0% and 100%
- However midday voltage is higher than off peak(night) voltage for 100% SSEG.



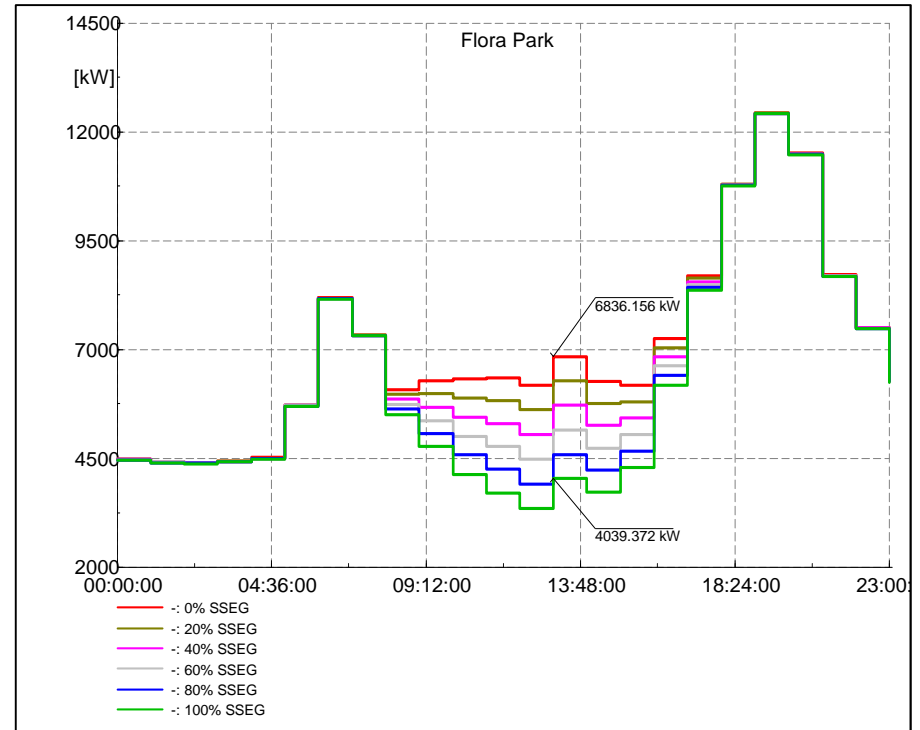
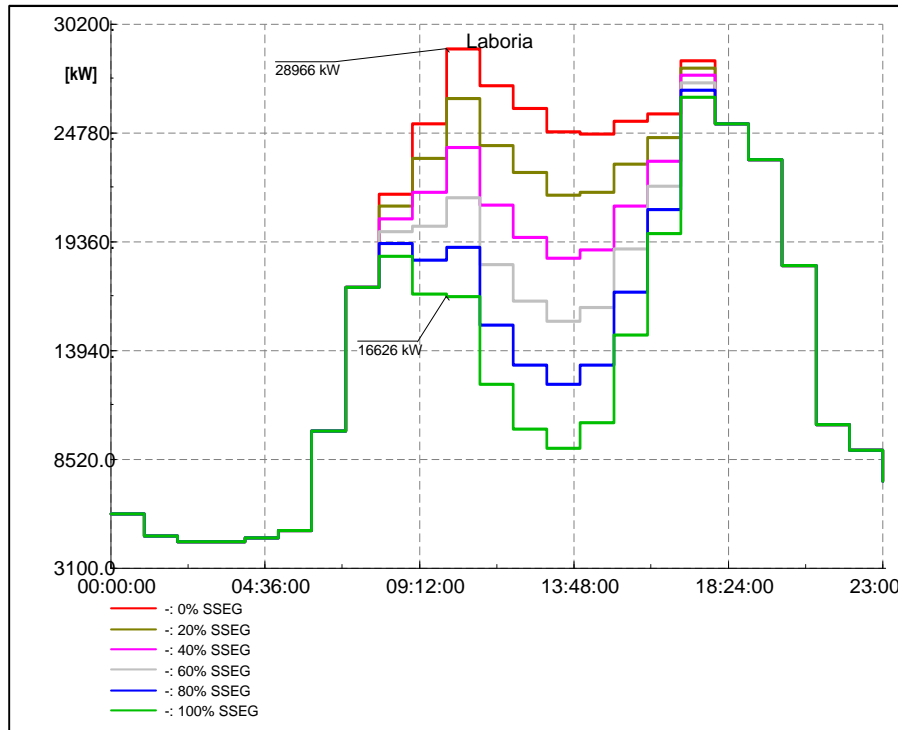
Power Flow Impacts – Peak Loading Summer– Varied SSEG Levels



- 0- 100% SSEG
- Total power flowing into the Laboria/Flora Park network (sum of all feeders)
- Peak loading considered



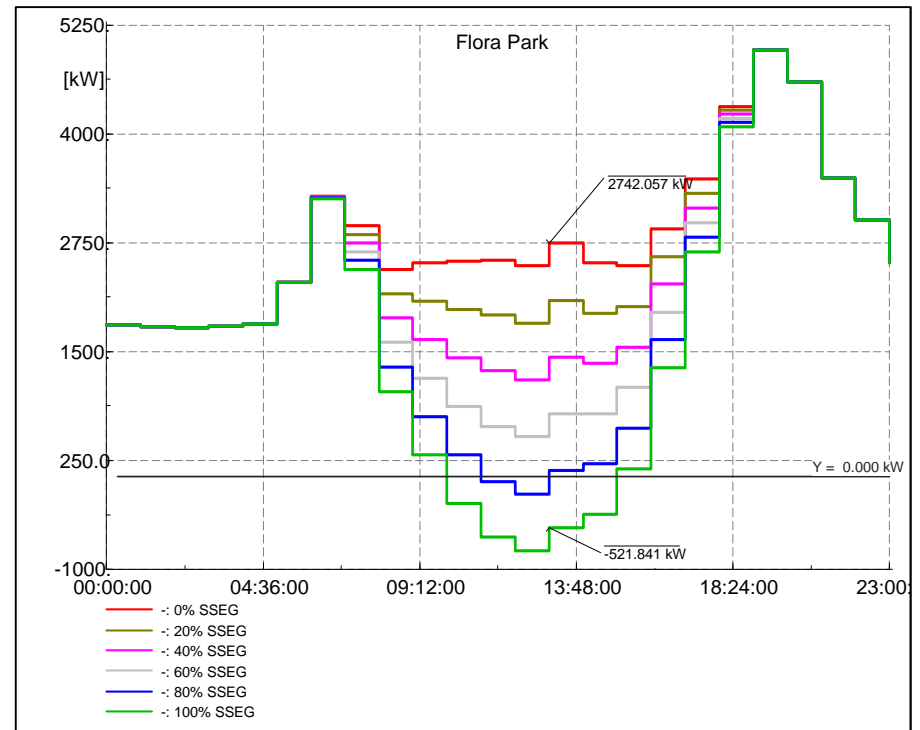
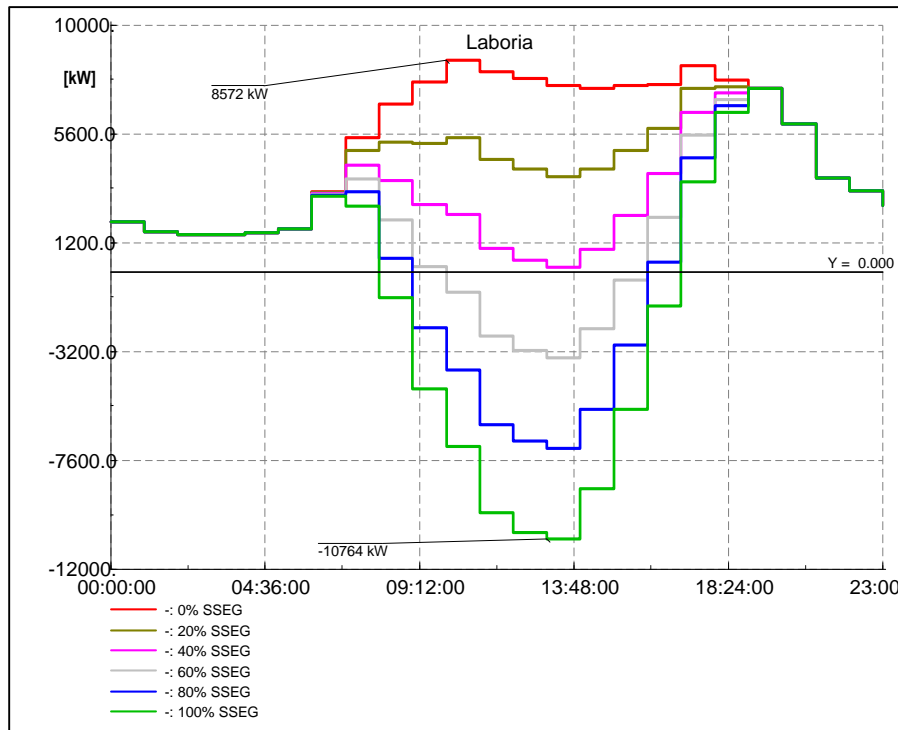
Power Flow Impacts – Peak Loading Winter– Varied SSEG Levels



- 0- 100% SSEG
- Peak loading considered



Power Flow Impacts – Minimum Loading Summer– Varied SSEG Levels



- 0- 100% SSEG
- Peak loading considered
- Reverse power flow noted from approximately 40% SSEG penetration level.
- Evening peak still requires supply from municipality



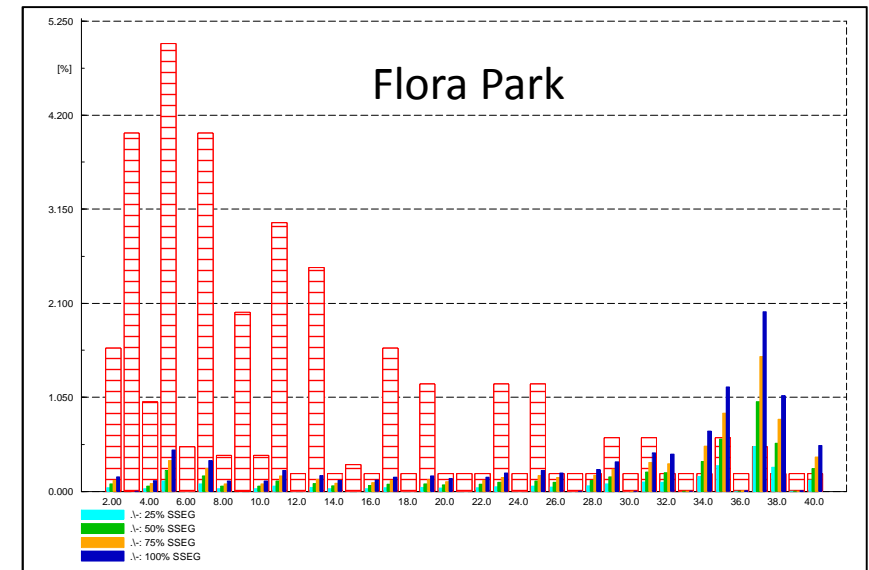
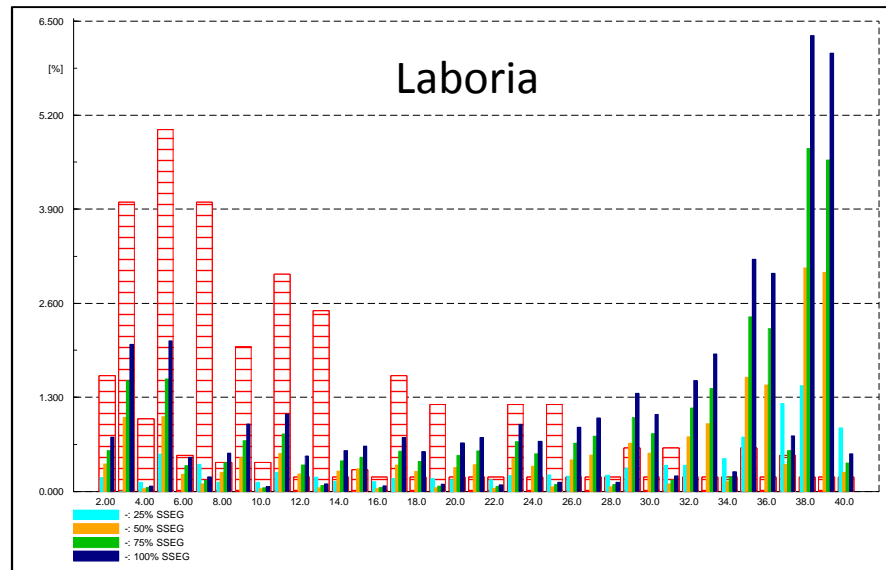
Harmonic Impacts

- PV inverters produce harmonics, though much effort has gone into reducing the amount of harmonics produced by modern inverters
- However the **concern** is that when there is large penetration of SSEG in networks, what will the **cumulative effect** be **of all the harmonic current injections from the inverters**.
- Since there are so many **different manufacturers with different harmonic current injection spectrums**, the choice of harmonic injections is difficult.
- As such the **worst case harmonic current injections permitted by the IEC (EN 61000-3-2:2014)**, for an inverter was used as the harmonic current injection spectrum in the study.
- Harmonics are measured at the HV/MV substation, MV busbar.

Harmonic Impacts - Assumptions

- The following assumptions are made with the network model;
 - **Linear network impedance** assumed for the HV network
 - **No skin effect** on cables considered hence this will lead to worst case calculated distortion levels
 - **No background harmonics** are considered from the network side
 - All **loads modelled as impedance loads** with only the cable capacitance of the networks considered

Harmonic Impacts



- For **higher order harmonics** (>20th) the **voltage harmonics exceed** the allowable NRS limits.
- **Network resonance** around the **38th order** found which is consistent with the frequency response of LV & MV cables

- The **harmonic distortion increased** with **increased levels of SSEG** penetration and the results are as expected.
- For **lower order harmonics** < 20th order, the harmonics are well **below the NRS limits**, even with 100% penetration



Harmonic Impacts

- The results of the studies for these networks, show that even with **extremely high SSEG penetration levels**, the impact of the PV inverters on the **network harmonics is within acceptable limits**
- It must be noted that these **harmonics study results are heavily dependent on the network that is being studied** since clients may also have power factor correction and filtering equipment that will affect the harmonics in the network. (not considered in this study)
- Some networks may contain equipment that may cause network resonances. These resonances could cause harmonic distortions that exceed NRS planning guides.
- **It is highly recommended that each network be studied independently in order to assess the impacts SSEG will have on the harmonic distortions.**

Impacts on Energy Sold (Revenue)

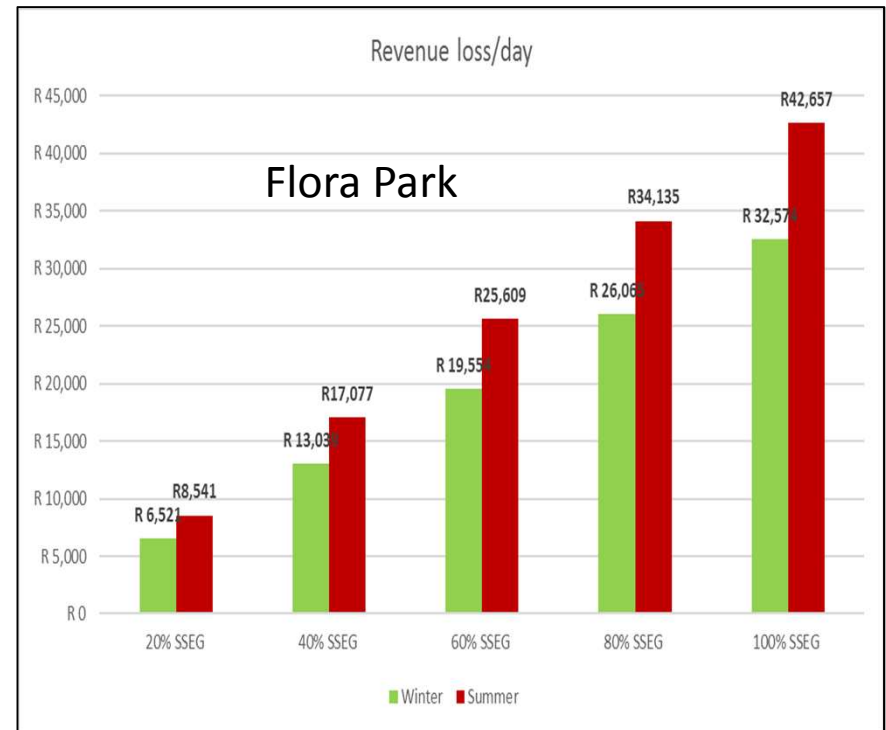
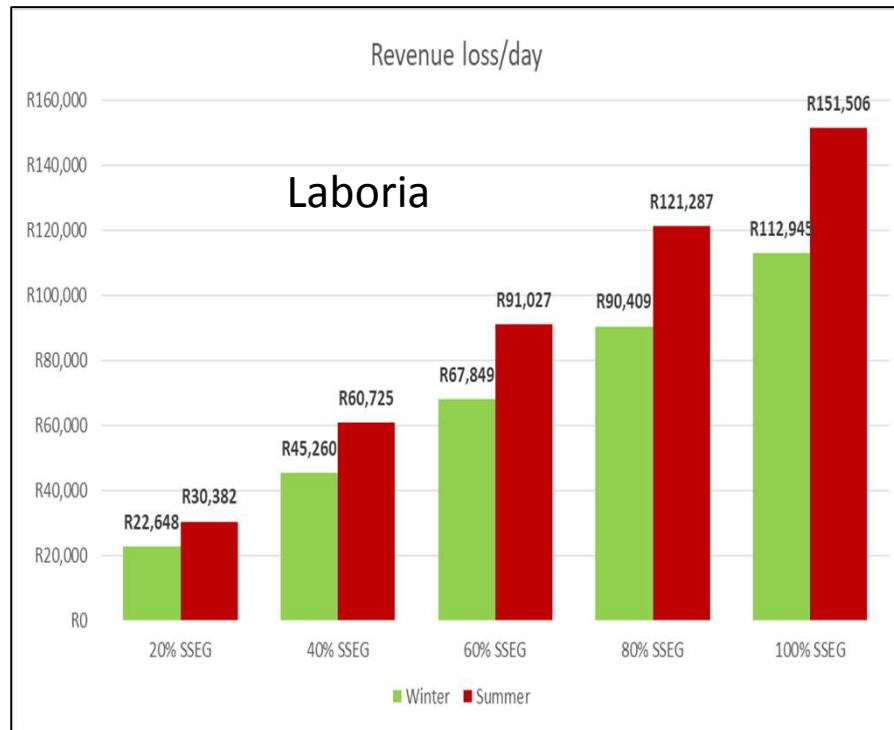
- With increased levels of SSEG penetration there is a significant impact on the power that is drawn from the HV network into the MV network
- This will have a direct impact on the energy sales by the municipality (in the network being studied)
- Fixed tariff for sale of energy used for study
- Since the studies are conducted using load and generation profiles over a typical day, the effect on the energy sales can also be quantified

Customer	Tariff (c/kWh)
Domestic	177
Commercial	151
Industrial	65

Season Loading	Daily income from energy sales	
	Laboria	Flora Park
Summer Peak	R408 197	R223 578
Winter Peak	R445 999	R320 819
Summer Minimum	R139 296	R112 090



Impacts on Energy Sold (Revenue) – Peak Loading

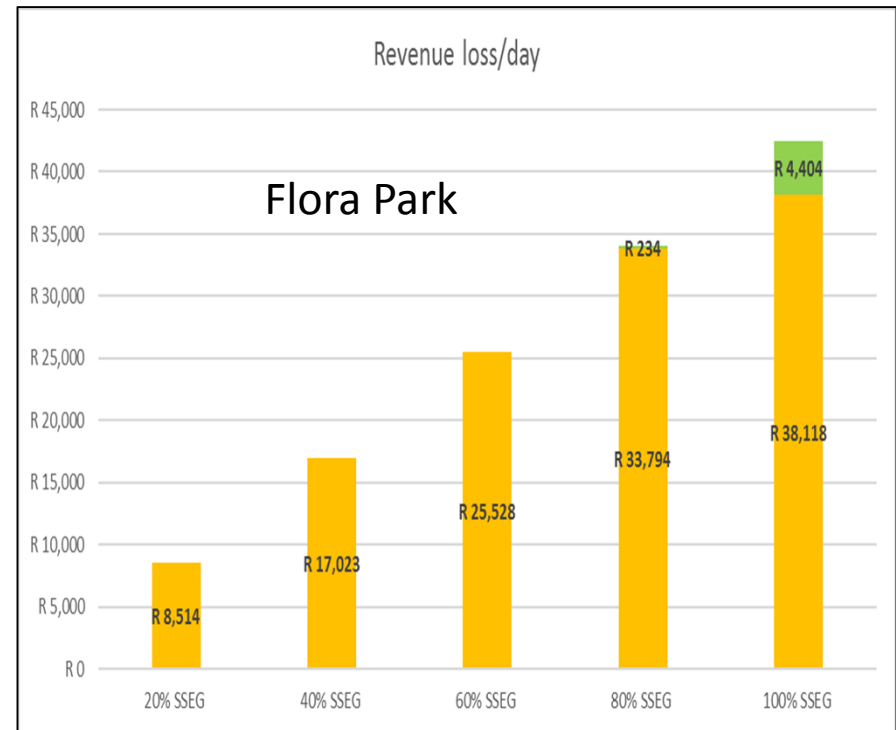
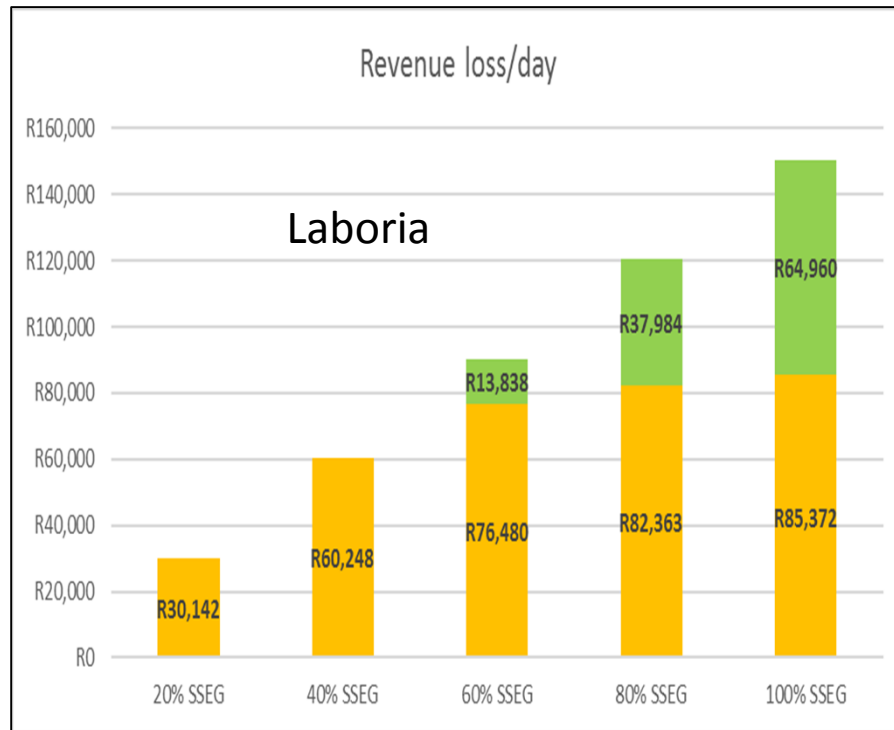


- Reality is that whilst industrial clients may have more financial resources to purchase SSEG, not all customers will install SSEG.
- Assuming a very favourable penetration rate of 60% for Laboria, then the daily reduction in energy sales
 - 22% in summer
 - 15% in winter.

- Reality is that all residential customers will not install SSEG.
- Assuming a very favourable penetration rate of 40% for Flora Park, then the daily reduction in energy sales
 - 8% in summer
 - 4% in winter.



Impacts on Energy Sold (Revenue) – Minimum Loading



- For the **minimum loading** cases there is **reverse power flow** from specific levels of SSEG penetration and above
- All **excess power** that is generated from SSEG is **actually income** thus reducing the loss of energy sold
- It must be noted that since the municipality has **no official feed-in tariff**, **excess power** that is generated from SSEG installations, comes **at zero cost** and can still be sold to nearby customers, thus this SSEG power becomes a source of income for the municipality (with no cost)



Impacts on Energy Sold (Revenue) – Minimum Loading

- It must be further noted that the **loss of revenue** from energy sales is **not entirely incurred by the municipality** since they do not have to pay Eskom for this unsupplied energy
- Also the losses for transporting the power from Eskom intake points to the customer is saved. As such the **municipality will only lose their 'mark-up' portion on the energy sold**
- For the **excess SSEG energy**, there is no cost of sale (no feed in tariff) hence this is a **net income to the municipality** (zero cost of sales)

CONCLUSIONS

- Even with the varied levels SSEG outputs, **cloudy and sunny days and also winter vs summer**, the **impact** on the **voltage regulation** on MV feeders is **minimal** and within acceptable variation levels
- The level of SSEG penetration does have an impact on the power flow in a network and it is **important to accurately model the load profiles of customers** in the network to accurately determine the expected changes in power flows
- Even when following the NRS 097-2-3 guidelines, there are **certain conditions where by reverse power flow** from MV to HV can occur (low loading, high SSEG penetration levels)

CONCLUSIONS

- Harmonic distortions increase with increased levels of SSEG penetration however these harmonic distortions are below NRS limits. NOTE: Harmonic distortions are dependent on the network design and equipment installed within that network hence each network must be studied independently to determine the impacts the SSEG will have on that network
- With no-feed in tariffs, any excess energy from SSEG installation can be sold and used to offset expected reduction in energy sales revenue
- Utilising the modelling techniques of these studies, the municipalities can quantify the expected reduction in energy sales. This can then be used to determine accurate fixed network charges in order to minimise the effect of reduced energy sales



Acknowledgements

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THANK YOU

