SA Energy Storage 2017

Impacts of residential PV installations on MV networks, with and without battery storage

by Geeven V. Moodley, Miriam S. Thopil and Glenn D. Jennings, *Digsilent Buyisa*

ee publishers

Overview

- Objective of study
- Simulation Model and Assumptions
- Studies with Battery storage only
- Studies with PV and Battery Storage
- Conclusions and recommendation

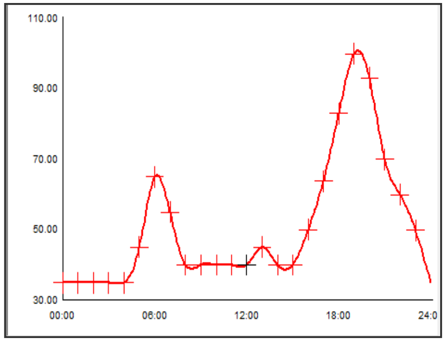
Objective of Study

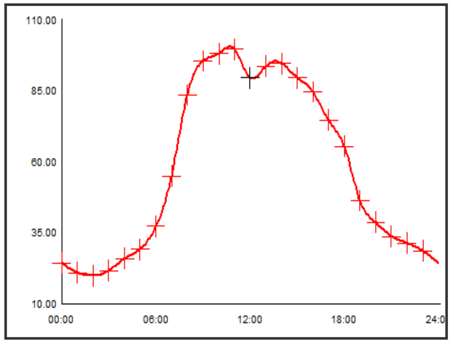
- In 2016 Digsilent Buyisa provided technical support to 4 municipalities in the area of SSEG, and it was realised that there is **much misconception about the impacts SSEG, in particular PV, will have on the technical and financial performance of the municipality**.
- In order to address this, **Digsilent Buyisa conducted extensive studies** on the impacts of SSEG (PV) on the MV networks of municipalities including **the impacts of revenue from energy sold***
- With the **increasing availability of storage systems**, in particular battery storage for domestic and commercial use, questions was then raised about
  - **1. The impact of storage only on MV network performance, both technically and financially? and**
  - **2. The impact of both storage and PV installations on the same network?**

* G. V. Moodley, G. D. Jennings, V. Pillay, N. Reitz and J. Govender, "Impacts of PV on Typical South African MV Networks," in *CIGRE Southern Africa Regional Conference*, November 2017

Simulation model and assumptions considered

- Network used was Flora Park in Polokwane Municipality with **87% residential and 13% light commercial clients**.
- All clients on **shared LV feeders**.
- Studies done using **Digsilent PowerFactory 2017**.
- **Load profiles*** derived for each customer class.
- **Peak network loading** occurs in **winter** with the **summer peak** approximately **40%** of the winter peak.



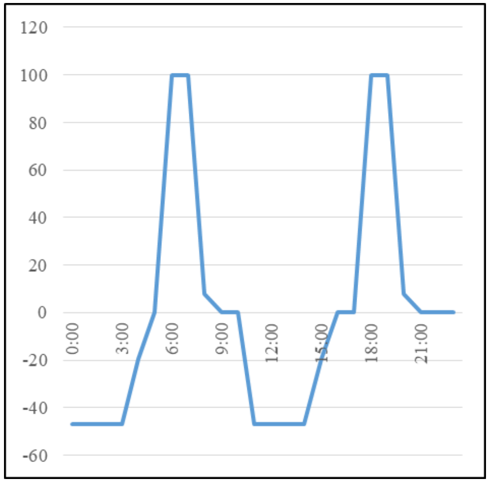


* J. A. Jardini, C. M. Tahan, M. R. Gouvea, S. U. Ahn and F. M. Figueiredo, "Daily load profiles for residential, commercial and industrial low voltage consumers," IEEE Transactions on Power Delivery, pp. 375-380, 2015.

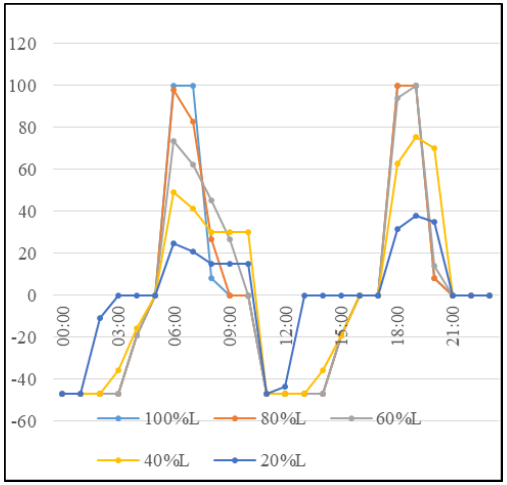
Simulation model and assumptions considered

- Li-ion type, 52V-460Ah-24kWh
- 3 battery charge/discharge profiles derived
  - **Full discharge:** batteries discharge their full rated output during peak periods (06:00-10:00 and 18:00-20:00) regardless of load
  - **Load following discharge:** In this case, inverters allow batteries to discharge during peak periods (06:00-10:00 and 18:00-20:00) till the battery reaches 10% of its maximum energy capacity. However, the dispatch is such that it matches the load value subjected to its maximum rated output limit.
  - **Conservative discharge:** In this case, the battery discharge is limited to 50% of its maximum rated output, regardless of the load demand. The discharge takes place during peak periods (06:00-10:00 and 18:00-20:00) till the battery reaches 10% of its maximum energy capacity.

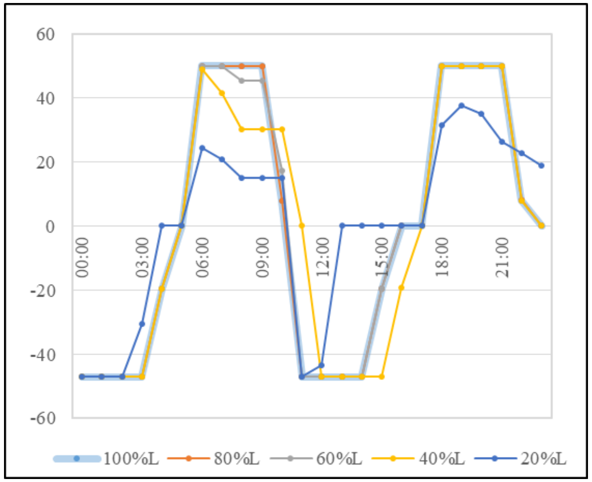
Simulation model and assumptions considered



Full discharge



Load following

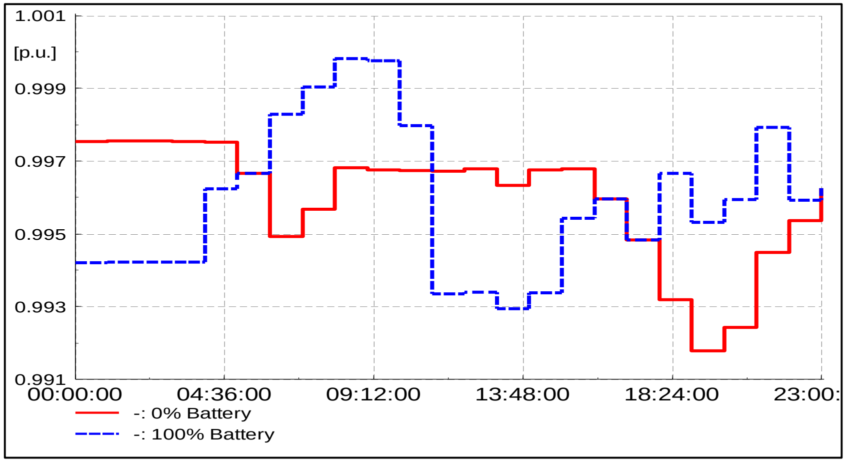


Conservative

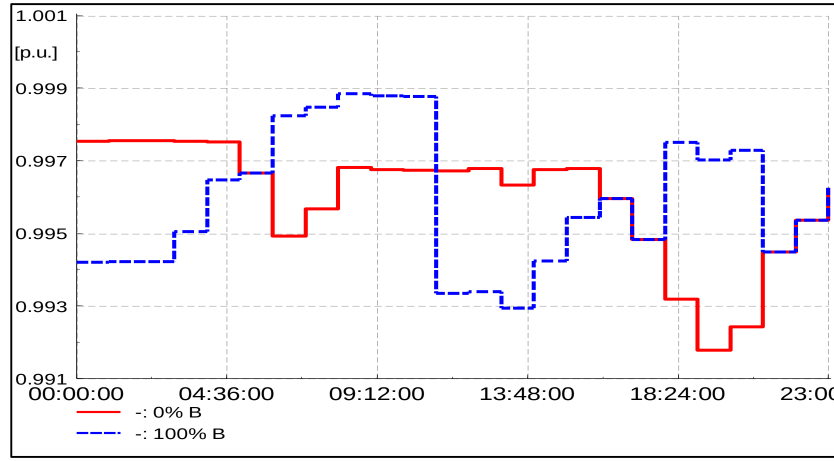
STUDIES WITH BATTERY STORAGE ONLY

Battery Storage Only

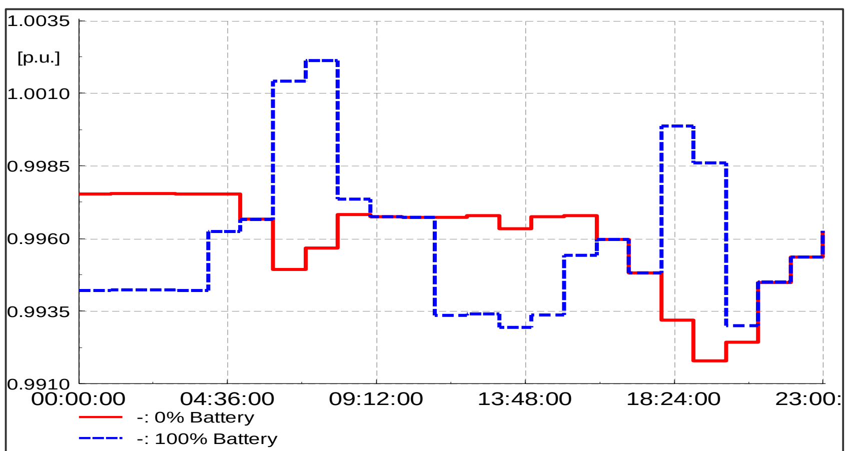
Impacts on Voltage Regulation



Conservative



Load Following

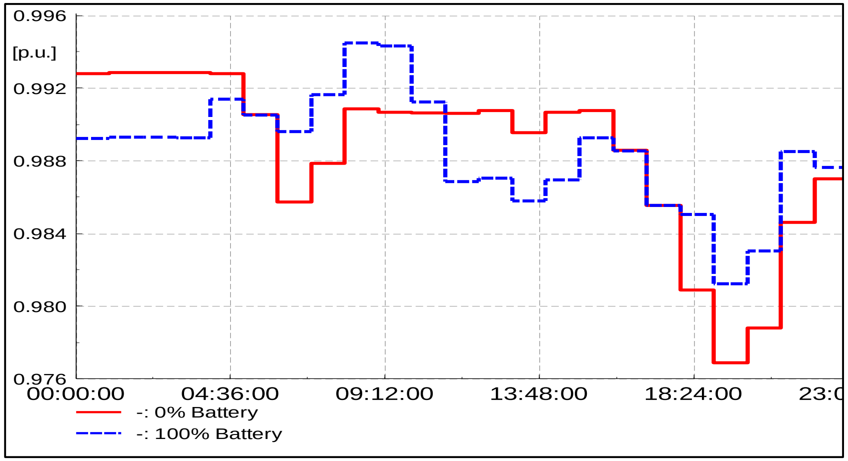


Full Discharge

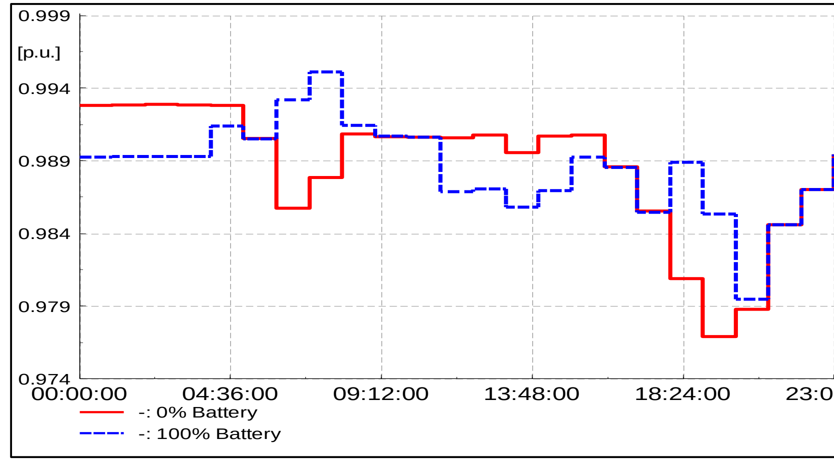
Minimum load

Battery Storage Only

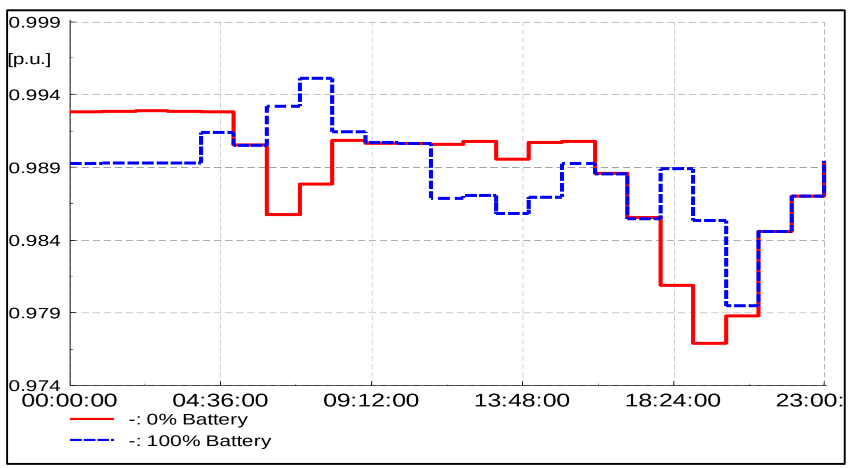
Impacts on Voltage Regulation



Conservative



Load Following



Full Discharge

Maximum load

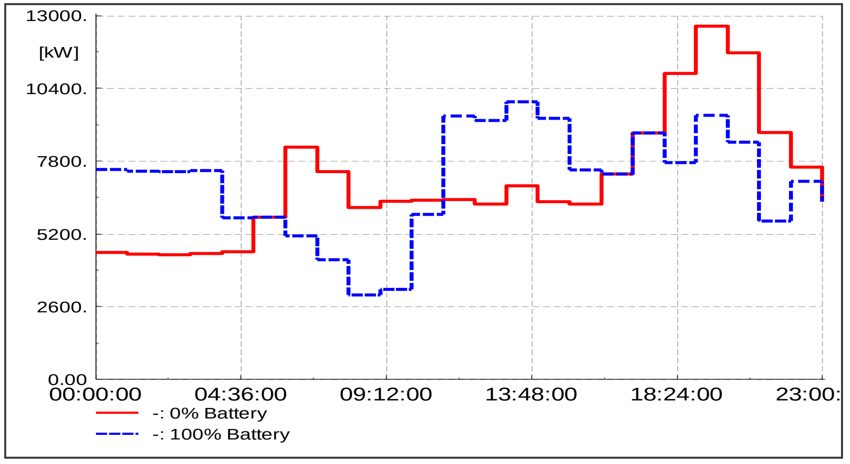
Battery Storage Only

Impacts on Voltage Regulation

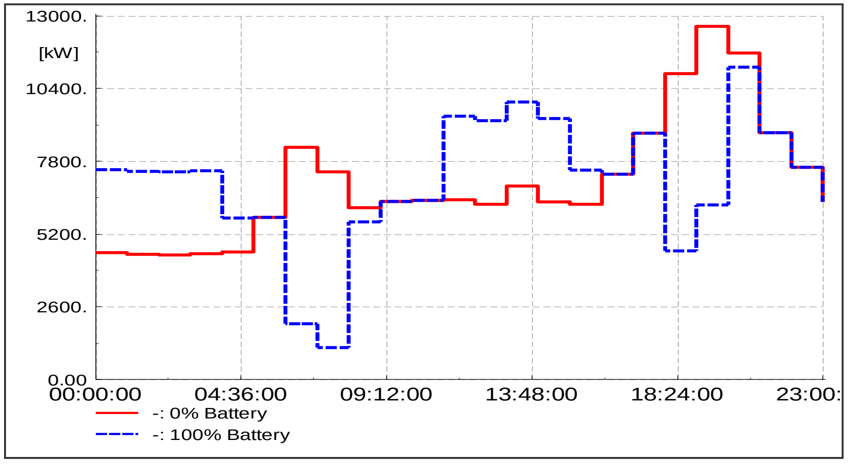
- The **voltage variation is < 1%** for all cases studied
- There is a distinct **shift in the voltage profile** with battery storage and the **shift is dependent** on the **charging** and **discharging** profile of the battery.
- The battery **storage** certainly **assists** the network voltage during the **peak loading period** 18h00 to 19h00 hours by increasing the voltage however for the morning peak the voltage with battery is higher than cases with no batteries.

Battery Storage Only

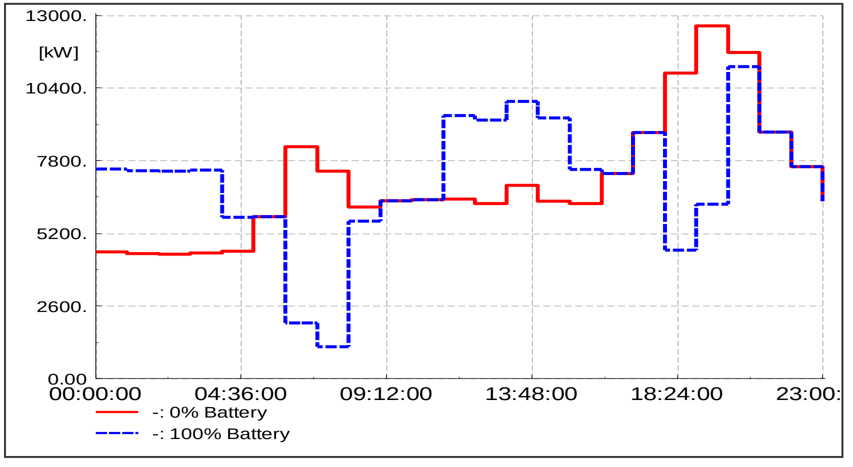
Impacts on Power Flow



Conservative



Load Following

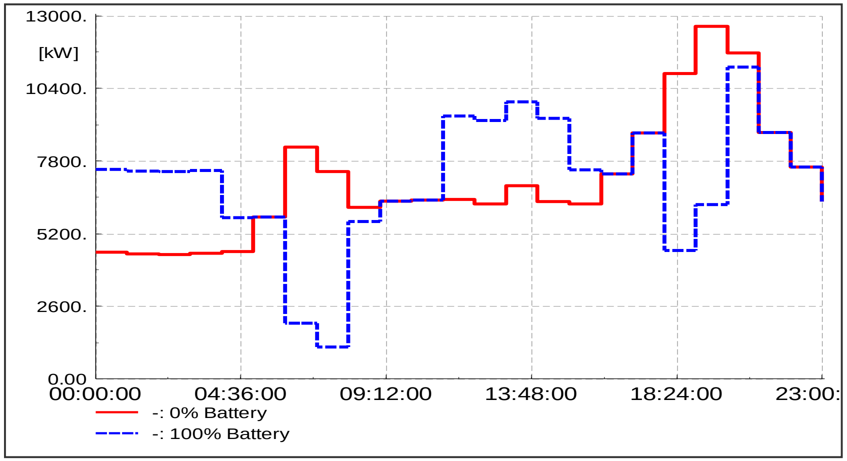


Full Discharge

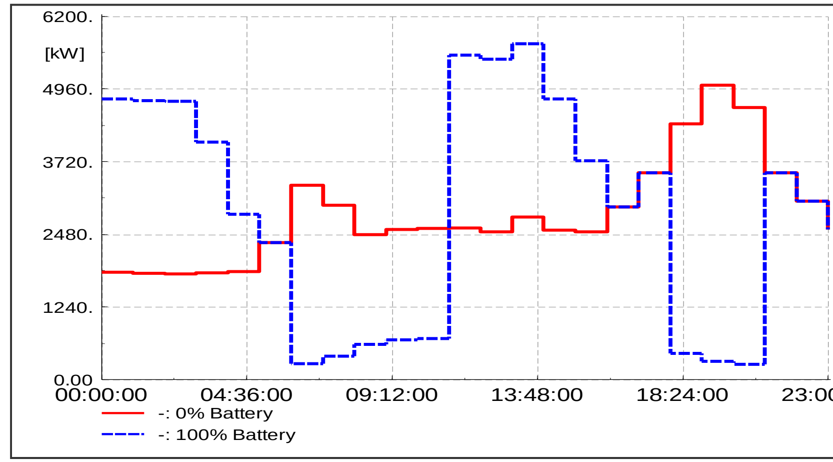
Maximum load

Battery Storage Only

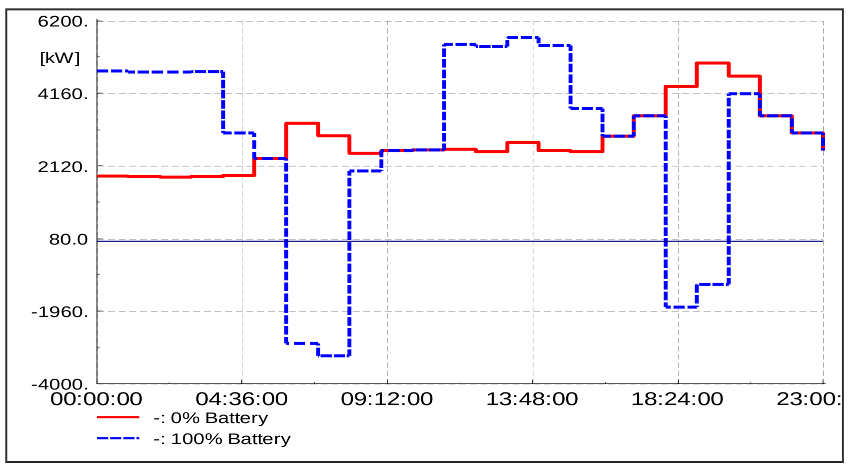
Impacts on Power Flow



Conservative



Load Following



Full Discharge

Minimum load

Battery Storage Only

Impacts on Energy and Revenue

Type of battery operating mode	Conservative Discharge (kWh)	Full Discharge (kWh)	Load Following Discharge (kWh)	No Batteries (kWh)
Maximum network loading	169 258	169 309	169 309	169 313
Minimum network loading	68 100	68 194	68 089	67 987

Customer Type	Tariff (c/kWh)
Domestic	177
Commercial	151

	Daily income from energy sales			
Type of battery operating mode	Conservative Discharge	Full Discharge	Load Following Discharge	No Batteries
Maximum network loading	R 293 865	R 293 955	R 293 955	R 293 962
Minimum network loading	R 118 235	R 118 399	R 118 243	R 118 040

- Battery storage does not cause a reduction in the energy sold.

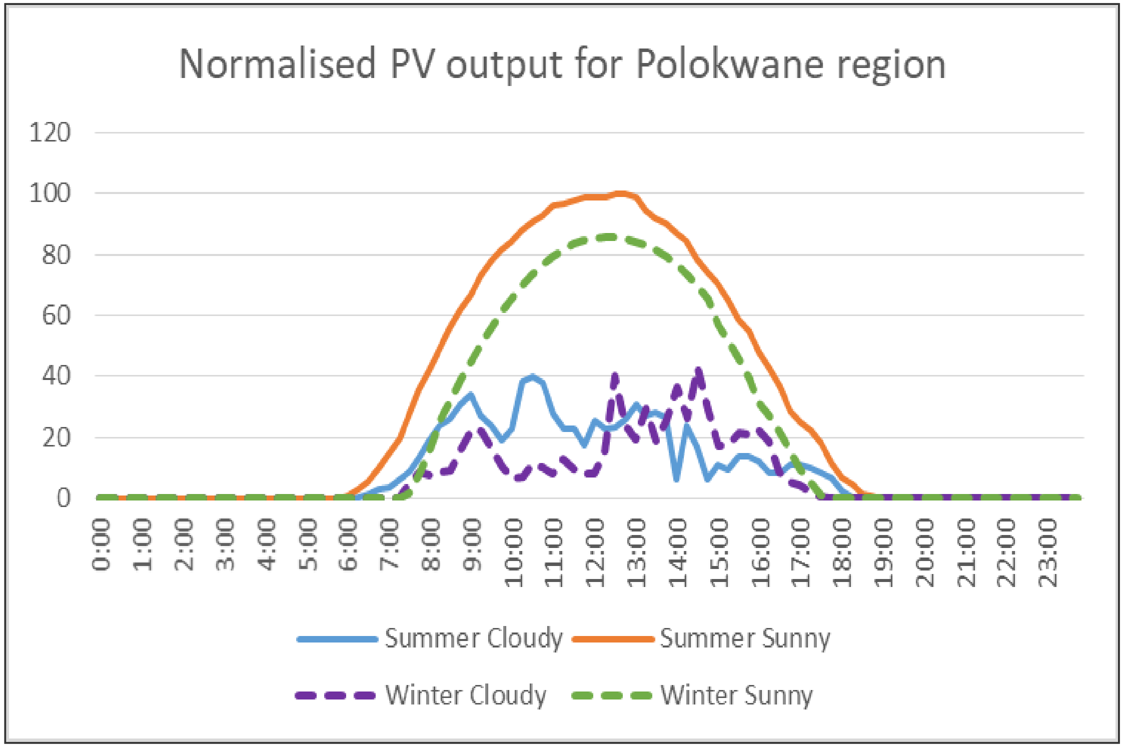
STUDIES WITH PV AND BATTERY STORAGE

Assumptions for the PV installations

- **NRS 097-2-3** was used as the main guide to size the PV installations.
- **Residential customers** are connected using a **60A connection breaker** (notified maximum demand = 13.8kVA). These customers are on shared LV feeders as such a residential customer will be limited to 25% of the total NMD, i.e. the PV installation is limited to **3.45kVA** (3.45kW).
- All **commercial customers** are also on shared LV feeders hence will also be limited to maximum PV 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, **not possible to apply this criteria** is. As such it could not be considered in the studies.

Assumptions for the PV installations

- PV generation profiles were for a **4kWp**, Sunny Tripower 6000TL-20 inverter installed in Polokwane.
- Data of generation records* analyzed and normalized generation profiles for sunny and cloudy days, as well as winter and summer derived.



*SMA Solar Technology AG, "Sunny Portal," [Online]. Available: https://www.sunnyportal.com/Templates/Content.aspx?ContentTitleId=DataProtectionDeclaration_title&ContentId=touDocKey_DataPrivacy

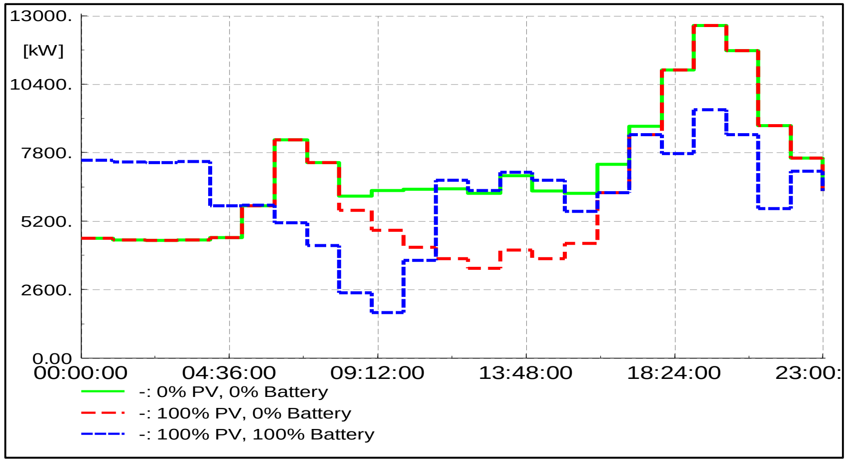
Impacts on voltage regulation, energy and revenue

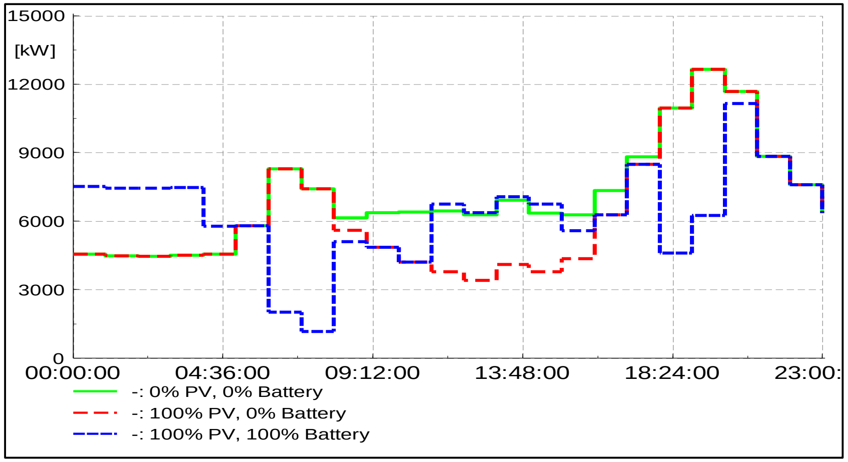
- Voltage:
  - Studies with **batteries only** show that the voltage variation is **<1%**.
  - Studies with **PV only*** show the voltage variation is **< 1%**
  - Safe to assume with **both**, **voltage variation will be <1%** (for this network)

- Energy and Revenue
  - Studies with **batteries only** show **no reduction in energy** and **revenue**
  - Studies with **PV only*** show **up to 37% loss in revenue**
  - **Reduction in energy sales (revenue) will be due to PV installations and not battery / storage options**.

* G. V. Moodley, G. D. Jennings, V. Pillay, N. Reitz and J. Govender, "Impacts of PV on Typical South African MV Networks," in *CIGRE Southern Africa Regional Conference*, November 2017

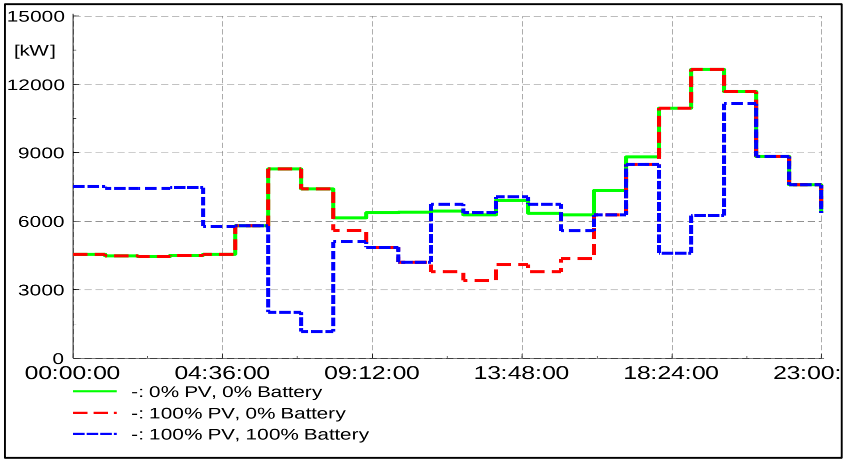
Impacts on Power Flow





Conservative

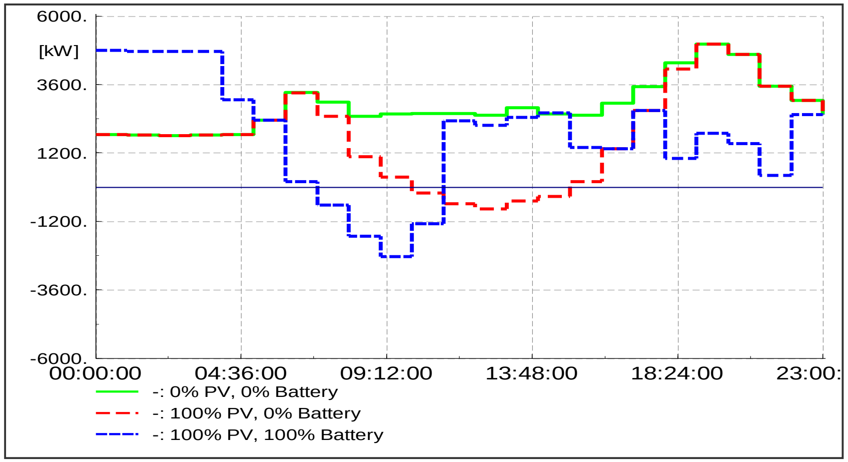
Load Following



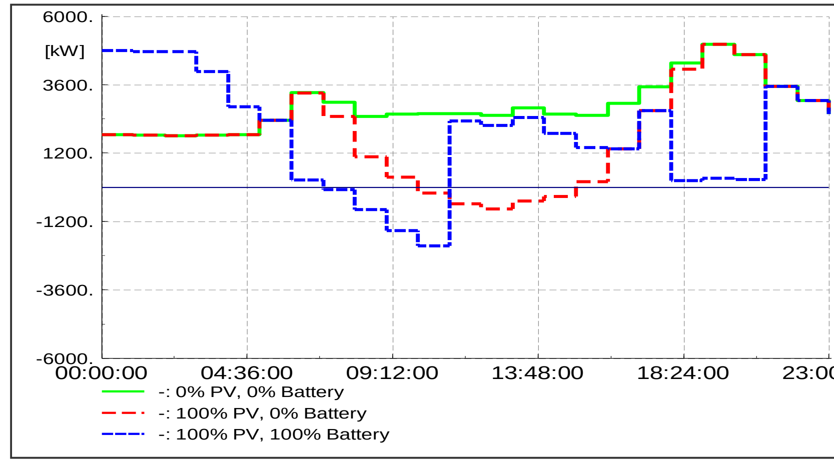
Full Discharge

Maximum Load

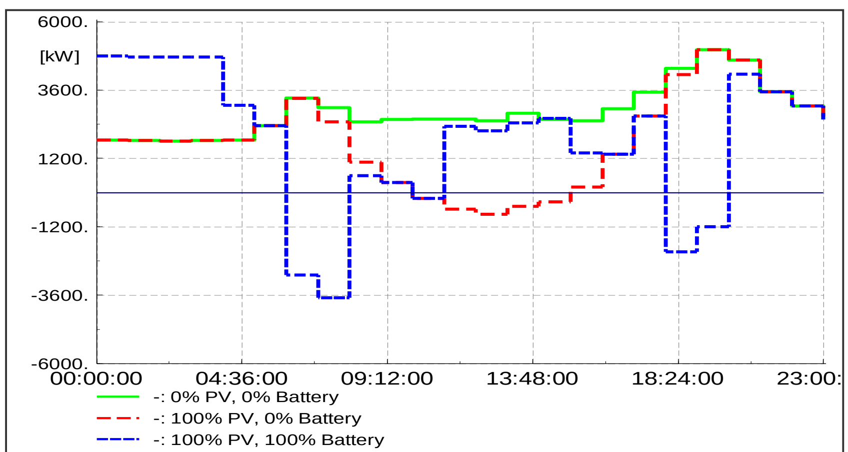
Impacts on Power Flow



Conservative



Load Following



Full Discharge

Minimum Load

Conclusions and Recommendations

- Even with the introduction of batteries in every consumer household in the Flora Park network, the **impact on the voltage regulation of MV feeders is minimal** and within acceptable variation levels.
- The **level of battery penetration and mode of battery operation does have an impact on the power flow** in the 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.
- With **batteries only**, the amount of **energy sold** in the network is **approximately the same** as the network without batteries. In fact energy sales should increase when taking into account efficiency of the battery operation.

Conclusions and Recommendations

- The introduction of **PV and batteries** into the network again showed **minimal impact to the network voltage**, for the network studied.
- The **municipalities can quantify the expected reduction in energy sales due to PV integration**, and this can then be used to determine accurate fixed network charges in order to minimise the effect of reduced energy sales.
- It is **recommended that the load following discharge profile is implemented on battery storage systems**. Even with a conservative discharge profile, there may be large power variations and reverse power flow.

THANK YOU!

Geeven Moodley

Tel: 087 351 6159

Email: info@digsilent.co.za

Web: www.digsilent.co.za