TYPICAL TECHNICAL BEHAVIOUR OF LV NETWORKS, WITH VARIED LEVELS OF RENEWABLE PENETRATION

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ABSTRACT

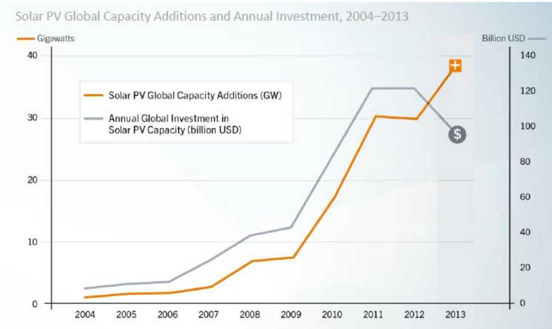
The installation of LV, PV embedded generation is steadily growing worldwide, largely driven by the reduction in PV module costs. In South Africa there are several technical concerns about the impact high penetration levels of embedded PV generation will have on LV networks. A typical 400V network was taken and the impact of 23% and 54% penetration of embedded PV generation was analysed. The results show that for moderate penetration levels the effect on the feeder voltage profile can be positive. Reduction in losses and the reduction in feeder peak demand are also noted. Where there is little correlation between generation pattern and load profile, the shifting of the feeder peak and voltage 'swings' are noted.

1. INTRODUCTION

South Africa is still in its infancy wrt renewable energy installations and all of this is at transmission and sub-transmission level. However in countries with high penetration of embedded renewable generation, the bulk of this is at LV level, e.g. Germany has approximately 90% [1] of its total PV installation of 35.67GW [2] installed on rooftops. Current trends indicate that for the renewable market to really take off in South Africa, embedded generation needs to take place at LV level. The question then raised is what technical impacts is this going to have, on networks, which were designed to transfer power from the 'top down'. This paper will present results of studies that show the typical technical behaviour of LV networks, with varied penetration levels of renewable generation, and give some indication as to how to manage these developments.

2. GLOBAL TRENDS

Whilst South Africa still finalises the policies and regulations surrounding the installation of renewable generation sources at LV level, the world continues its development of renewable generation sources with 22.1% of global electricity being produced from renewable energy by the end of 2013 [3]. China and the US continue to lead in the investment into renewable generation. Most significant in 2013 was that there was more PV installed (39GW) than wind (35GW) [3]. This is a significant trend for South Africa because whilst solar geysers and heat exchangers remain a primary source of LV load reduction, PV panels are the most viable source of electricity generation. To further strengthen PV installation growth worldwide, the installed capacity of PV increased whilst the investment into PV decreased, as shown in Figure 1. This is primarily due to the reduction in module prices. Such a trend is significant for developing nations as the cost of renewable energy still remains a major factor.



<u>Figure 1 - PV growth despite reduced investment for 2013 [3]</u>

3. CONCERNS OF EFFECTS OF EMBEDDED GENERATION ON LV NETWORKS

LV networks are traditionally designed to transfer power from the 'top-down'. With global trends indicating the steady increase in installations of PV at LV level, the concerns on the adverse effects of LV embedded generation needs to be carefully studied and managed, especially as South African networks are different in their design from European networks.

Some of the technical concerns currently being discussed are;

- Effects on voltage
- Effects on thermal loading and peak demands
- Effects on the network losses
- Effects on feeder protection
- Safety

These concerns are certainly relevant, and analysis of the impacts of varied levels of embedded generation at LV level is therefore vitally important to quantifying these effects.

4. CASE STUDY RESULTS

4.1 LV feeder studied

In order to perform studies a typical LV feeder was chosen. The feeder has the following properties;

- 400V
- 470m long, cable network
- Peak demand = 198kW (no embedded generation)

The embedded generation considered on the feeder was PV at randomly chosen injection points. The penetration levels studied were;

- 0%, 23% and 54% of peak feeder demand (0kW, 45.9kW & 107kW)

Figure 2 is a schematic representation of the feeder.

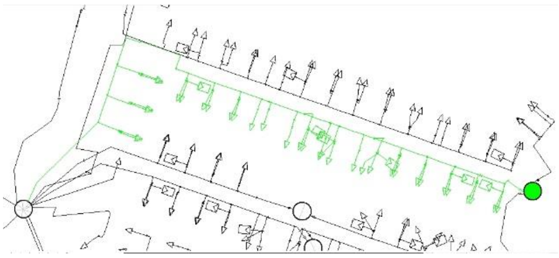


Figure 2 - Schematic diagram of feeder studied

All studies were done using Digsilent's Powerfactory software, V15.1 [4].

4.2 Generation & Load Profiles

Traditional network planning studies consider mainly the feeder peak demand. With embedded generation the nature of the generation and the time dependent generating pattern needs to be taken into account. As such, using only the peak load demand is no longer adequate to fully analyse the feeder and a full load profile over the same time period as the generating pattern is required.

For the feeder considered, 2 load profiles were used, namely a domestic load and a light commercial/professional load. The mix of the load types in the feeder was 33% domestic to 67% light commercial/professional. Figures 3 and 4 show the profiles of the load types.

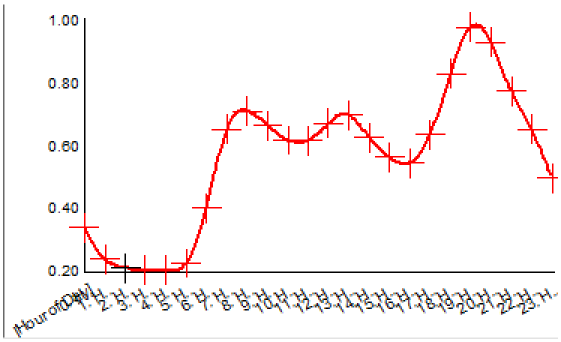


Figure 3 - Domestic load profile with peak around 7pm

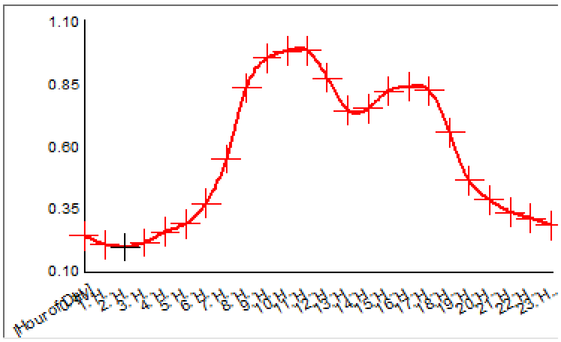


Figure 4 - Light commercial /professional load profile with peak at 12pm

The generation profile of a typical PV plant must also be considered. Figure 5 shows the generation profile of the rooftop PV with typical operating hours between 6am and 6pm.

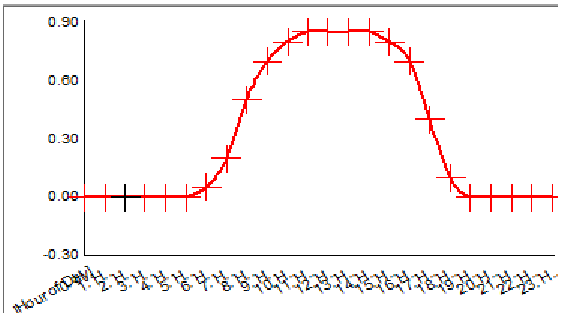


Figure 5 - Rooftop PV generation pattern

4.3 Effect on Voltage Profile

The feeder profile voltage was monitored at the infeed point (first load connection point) and at the last connection point along the feeder. No voltage changes at the MV/LV transformer was considered. The results indicate that the impact of the embedded PV generation on the feeder voltage profile is most significant at the end of the feeder. Figure 6 shows the feeder voltage over a day.

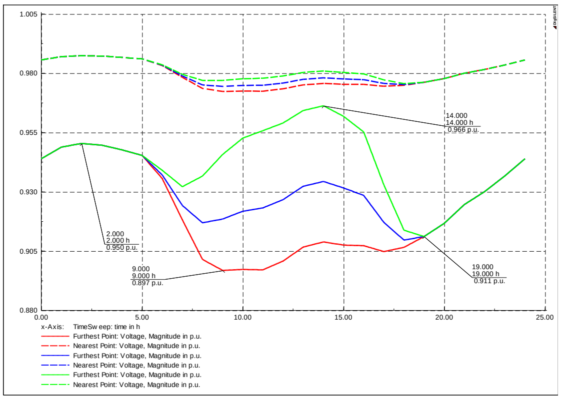


Figure 6 - Effect on feeder voltage profile

Whilst the effect on the voltage profile is most pronounced at the end point, the improvement in voltage profile is noted where the generation matches the load demand and there is a moderate penetration level.

In the case of no generation the maximum voltage swing is 5% occurring between 2am and 9am. With high generation penetration, a 5% voltage swing is still noted however it occurs between 2pm and 7pm in the afternoon. The results in this study show that the high penetration level shifts the maximum voltage swing, thought does not alleviate it.

4.4 Effect on Feeder Peak Demand

The effect on the feeder peak demand is shown in Figure 7. The results indicate a reduction in the feeder peak demand and a shifting in the time of the feeder peak.

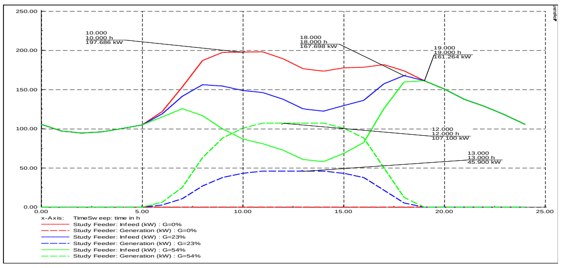


Figure 7 - Feeder peak demand.

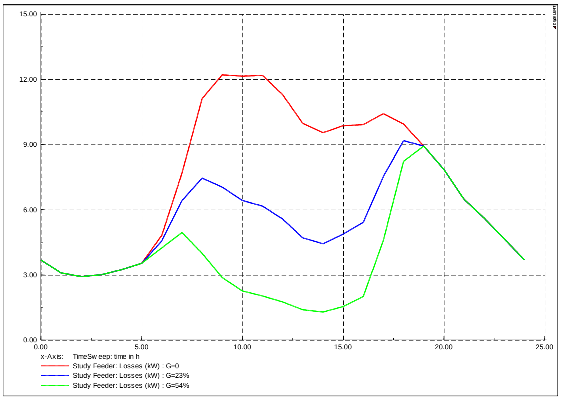
Most noticeable is that if the generation profile does not match the load profile there is no significant reduction in the reduced peak demand. Table 1 shows that the PV generation has managed to reduce the peak feeder demand that was predominantly caused by the light commercial loads, however an increase from 23% to 54% generation penetration has little effect on feeder peak which is caused by the domestic load peak at 7pm (after the PV plants have stopped producing power).

Table 1 - Reduction in feeder peak demand.

Generation	Feeder Peak	Time
0%	198 kW	10h00
23%	167kW	18h00
54%	161kW	19h00

4.5 Losses

The most significant reduction noted is with the feeder losses. LV networks are predominantly resistive hence the impact on losses will therefore be significant. Figure 8 shows the reduction in the feeder losses.



5. CHALLENGES FOR SOUTHERN AFRICAN LV NETWORKS

Unlike European LV networks that are balanced, South African LV networks are predominantly single phase. Load balancing between the phases is a problem that has long faced network operators. With single phase PV becoming more affordable, the concept of single phase 'generation balancing' is also likely to become a factor that has to be carefully assessed on a feeder by feeder basis.

In order to perform this feeder level analysis, knowledge of the feeder is required. Advanced database and GIS systems will be required in order to hold information such as;

- Feeder cable types and lengths
- Feeder peak demands
- Feeder load profiles
- Customer connection types

Further to this, this information will need to be processed and seamlessly passed to the simulation and analysis tools. Bulk analysis of multiple feeders will be required.

6. CONCLUSIONS

Embedded PV generation is going to become a reality as customers become more 'energy savvy' and the cost of PV modules continue to reduce. As such the network operators need to be able to understand and quantify the technical effects the embedded generation will have on LV networks.

Where correlation between generation and load profiles is high, the effects can be significant, especially with respect to voltage profiles and losses. Where little correlation is seen, the shifting of feeder peak times and voltage swings may be noticed.

Furthermore for relatively low to medium penetration levels the effects can be positive for LV networks especially on the voltage profiles. However the question it then raised, "What is a suitable allowable penetration level for a feeder?"

Detailed knowledge of LV networks is crucial to analysing and managing any adverse effects, varied penetration levels of embedded PV generation may have.

7. REFERNCES

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