POWER SNAPSHOT ANALYSIS: A NEW METHOD FOR ANALYZING LOW VOLTAGE GRIDS USING A SMART METERING SYSTEM

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ABSTRACT

The subject of this paper is to describe the method newly developed within the research project ISOLVES (Innovative Solutions to Optimize LV Electricity Systems). The objectives are to study LV grids in detail and to close gaps of knowledge about impacts on voltage levels caused by asymmetric load or feed, and real grounding systems. Therefore a smart metering system (AMIS-Siemens) has to be upgraded with special functionalities: All meters connected to the low voltage grid under consideration provide time-synchronously measured power and voltage. A triggering concept allows acquiring a useful set of snapshots.

INTRODUCTION

Problem: About 70% of the voltage band available in existing low voltage grids is typically allocated to for voltage drop at maximum load. This means that distribution grids are not designed for a high penetration of distributed energy resources (DER) such as PV systems. The assessment methods for planning the interconnection to the grid are based on worst-case assumptions due to the lack of detailed knowledge. Conservative scaling factors (e.g. 100% generation and 0% load) must be used in planning in order to ensure the compliance with the operational limits. Moreover, single phase components are usually considered in the interconnection assessment [1] by using the six fold power in order to take the voltage drop in the neutral into account. In order to be able to investigate impacts of DER on low voltage grids and to suggest suitable solutions to the voltage rise problem, a funded knowledge is needed.
Detailed network studies are necessary to quantify the impact of distributed energy resources and to quantify the cost-benefits of possible smart grids solutions allowing an efficient integration of DER into the LV grids. In absence of data, assumptions must be done. The assumptions have such a large impact on the results that the calculations are almost without value. By filling this gap in the knowledge of LV grids, it will be possible to get a better picture of the present situation and investigate smart grids solutions.

Solution: In the ISVOLVES:PSSA-M project a method has been developed to capture a synchronous image of all node-characteristics of the grid, the so-called "Power Snap Shot Analysis by Meters" (PSSA-M). The basic principle is to record at each meter simultaneously 900 measurement values (1-second-rms values for P, Q, U for 15 min) - After this recording period, a selected set of meters (10%-30%) sends trigger propositions. These consist of indices and node characteristics according to well defined criteria to the system control unit at the distribution station. The following criteria have been proposed and implemented into the meters: maximum and minimum voltage among the considered interval, maximal voltage unbalance, and maximal current asymmetry.. The most representative indices (trigger proposition) are evaluated by applying a special ordering algorithm. The output of the trigger selections is broadcasted to all meters which are responding by transmitting the related measurement values. The result is a set of synchronous measurements for several different interesting instants.

THE "POWER SNAPSHOT" METHOD

For the development and first validation of the solution described above, the Power-Snapshot-method had to be simulated. Therefore a case study with an exemplary LV-grid (Fig.1) was performed.

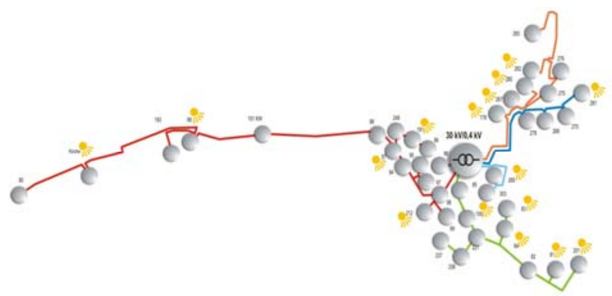

Figure 1. LV-Grid of the case study for development PSSA

This network consists of a distribution station feeding four branches. One of these branches has a total length of almost one kilometre, which can typically yield to voltage problems if PV generators are connected at the end of it. As loads detailed measurements of households (1-sec-rms) are used. These loads are unbalanced and have a "discrete" profile due to the switching of rather strong appliances only for a short duration. For the grounding, a resistance of 2 Ohm for each node has been assumed. Fig. 2 shows as an example the voltages calculated by load flow analyses for each 1-sec-Interval during a 15-min-time interval. The load fluctuations can clearly be seen and show that synthetic profiles can not be used without significant inaccuracy when modelling LV networks.

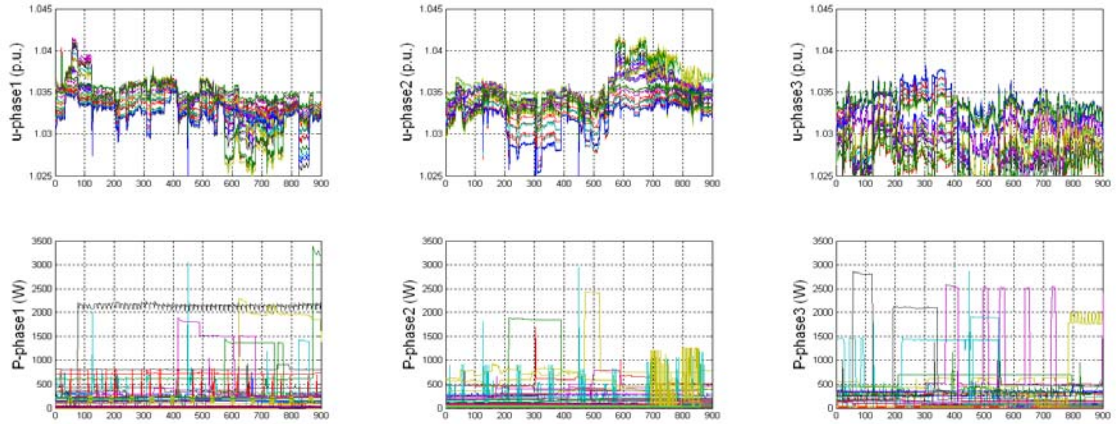

Figure 2. Loads and Voltages (1-sec-rms) at all nodes during 15 min

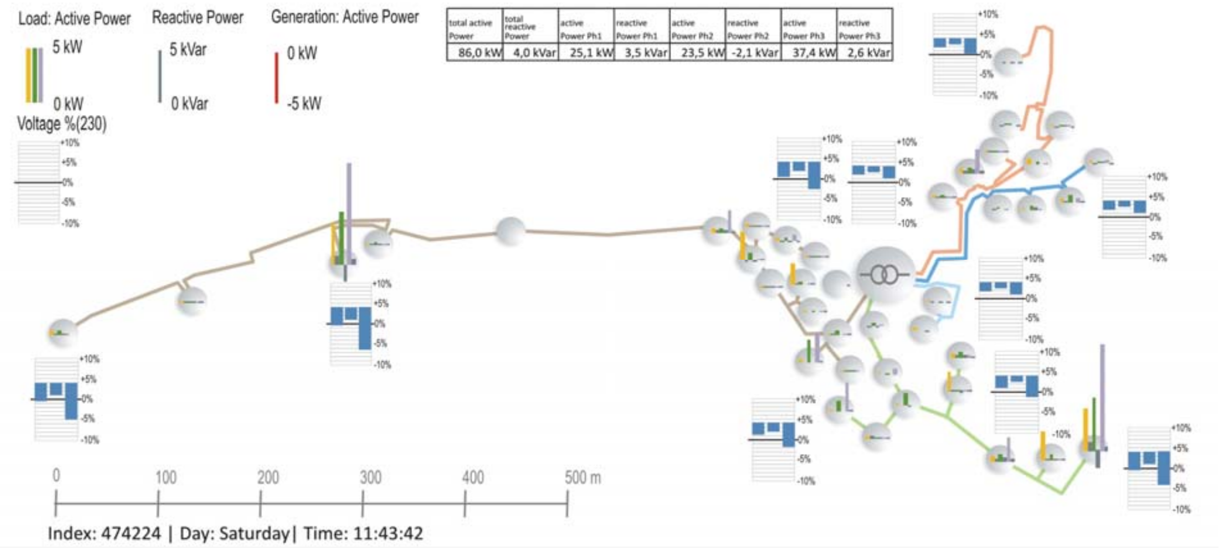

Figure 3. Snapshot of the 1-sec interval containing exhibiting the lowest voltage (Loads are shown at all nodes, voltages only for groups of nodes)

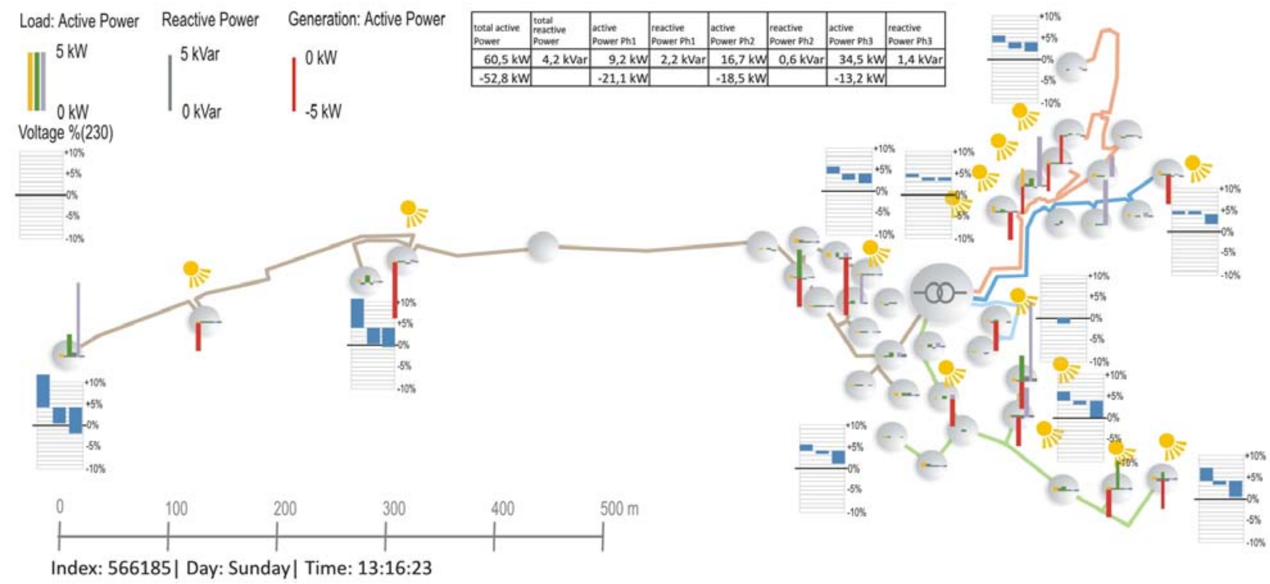

Figure 4. Snapshot for the 1-sec interval exhibiting the highest voltage corresponding to the maximal PV generation (3 & 6 kWp/ single phase)

In Fig. 3 and Fig. 4 the bar diagrams for the Voltage levels show voltage drops and rises from no load level (reference=230 V+4%). The load distribution in Fig. 3 causes voltage drops from +4% at the distribution station down to levels of -5%. The rest of the available voltage band is needed a reserve for drops occurring on medium voltage lines. In Fig. 4 the high penetration of PV-Systems with single phase converters typically results in a huge rise of the voltage. Depending on the medium voltage conditions at this time, the overvoltage protection might disconnect the PV-system from the grid. Nevertheless the technical rules published by the Austrian regulation authority require that the voltage rise caused by decentralized generation in LV-grids does not exceeds +3%.

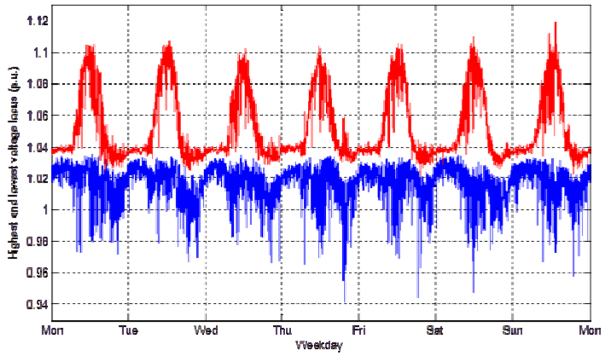

Figure 5. Highest and lowest voltage all over the LV-grid for each second of a “sunny” week-period (they occur at different nodes)

Fig. 5 shows the maximum and minimum voltage for each second of the week from all the nodes of the grid. The maximum values are following the typical PV-generation curve for the whole week for which a sunny weather has been considered. Simulations for cloudy and variable days have also been performed.

AMR System: The Siemens AMIS (Automated Metering and information System) consists of smart meters and a data concentrator located at the distribution station and uses DLC (distribution line communication) for organising metering processes and transferring the measured data. Furthermore grid analysing tools are currently implemented and will allow an automatic analysis of the snapshots as well as a graphical representation of the most important results.

Trigger concept: As there is no realistic way to transmit and process 1-second load and voltage profiles in real time, a trigger concept to get an interesting set of different representative Snapshots for each 15-min Interval had been developed. From 900 measured 1-sec-rms values the meters suggest the indices of the highest and lowest voltage (or 99,9% and 0.1% percentile) to be used for the snapshots. Meters close to each other usually measure similar voltage levels and therefore suggest the same indices. Only 10% out of 96 15-Minute-intervals of a day resulted for this network in more than five different indices. Almost thirty percent of suggestions are identically all over the LV-grid.

PSS- Campaign: To do a power snap shot campaign for the LV-Grid used in the case study 9 of 38 meters should be selected as a TM (Trigger Meter) to provide suggestions for snap shot indices. The evaluation of suggested indices is done by the DC (Data Concentrator).

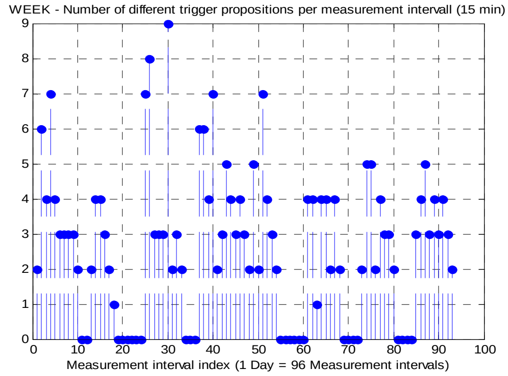

Figure 5. Number of different trigger proposition per measurement interval (minimal voltage - without PV, working day)

The decision rule simply follows the majority criteria.To avoid endless producing similar snap shots, suggestions are not considered anymore after a TM has been three time part of the majority. This rule is applied to 8 time windows of three hours for working days and not-working days. The whole procedure leads to self finishing analysing process.

The duration of a campaign depends on the size and density of the grid and the performance of data transfer between the station and the meters. In case that the communication for one snapshot can be done within 15 minutes, a continuous operation reduces the duration of a campaign to a few working days and days of weekend, depending on the number of meters. Depending on the requirements of the metering system the bandwidth for communication has to be shared. Therefore a campaign might take up to one or two weeks. A continues operation is not required at all because each 15-min-interval is a independent single analysis.
The concept does not contain any idea of permanent surveillance or monitoring, nor of discrete event capture. The aim is to get snapshots at different times of the day and to increase knowledge about impedances, load and generation distributions in the LV Grid.

The flowchart in Fig. 6 and the Cycle concept in Fig. 7 give an overview how to get from the signals finally a set of snapshots.

PSS-Analysis Process:-After collecting a few hundreds of snapshots in a database, similar snapshots are rejected within an automatic analyzing process. After this, the accuracy of the network model will be investigated by comparing the measured voltages with the voltage values obtained from the load flow calculations using the measured reactive and active power values rom the power Snapshot. The main source of inaccuracy is the modelling of the grounding for which experience is missing. These resulting grid models together with a representative load and generation data are prepared to be used in large numeric case studies. Therefore grid models and load data are stored in a database which can be directly addressed by a simulation tool (load flow).

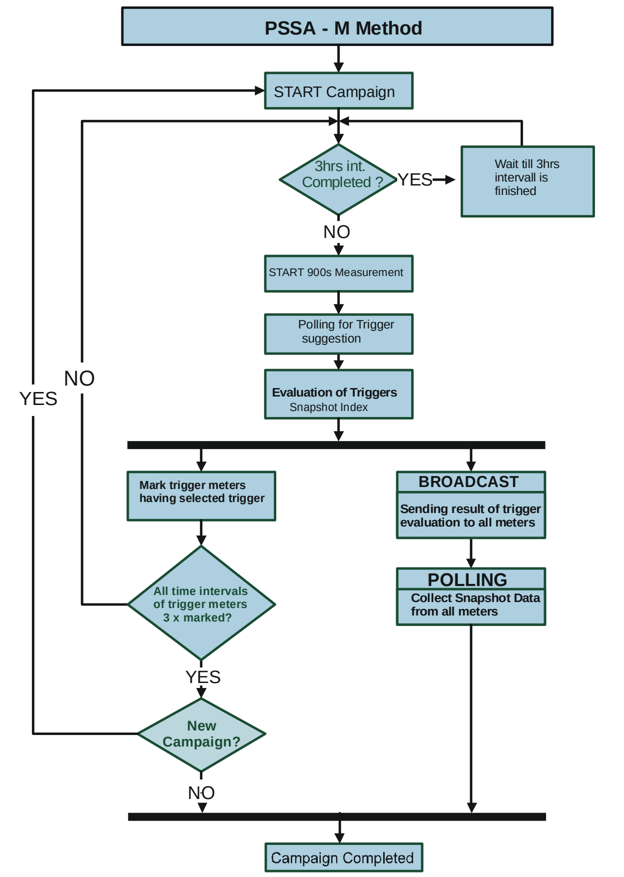

Figure 6. Flow chart of the Power Snapshot acquisition process

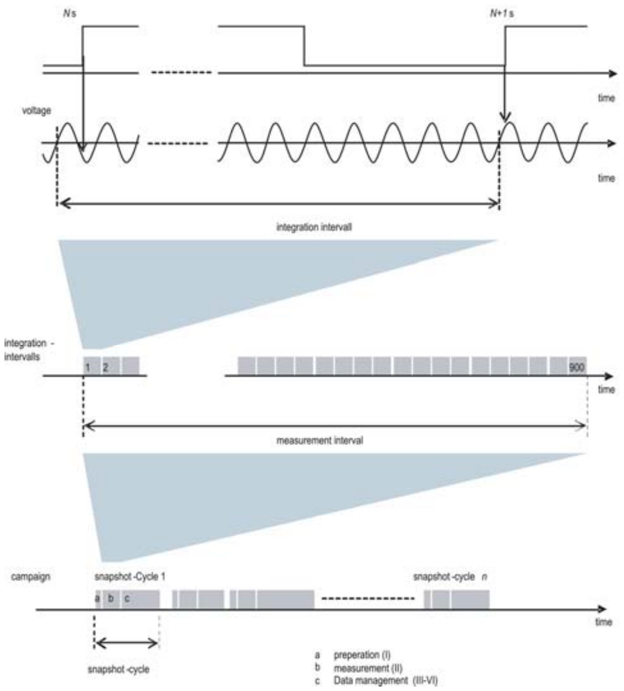

Figure 7. From the signal to the campaign

CONCLUSIONS & OUTLOOK

On the basis of the proposed PSSA-M method, smart meters are prepared to do synchronous distributed measurements. The analyzing process is done by load flow calculations using the four wires grid model including grounding. The differences between calculated and measured voltages will allow to develop realistic grid models and to learn about given uncertainties. The developed grid models and measured loads can be used to simulate future scenarios with high penetration of PV-Systems or loading e-vehicles for single phase or three phase components.

Once the system is fully deployed, several campaigns will be launched and on the basis of the results, the method will be further developed and improved. By analyzing up to 1 Mio snapshots from about 100 different low voltage networks, the potential for implementing smart grid approaches for an active network operation of LV networks will be evaluated by simulations.

Outlook: In future this method might be useful for analyzing the performance of smart grid systems in operation. Further developments shall provide useful applications and tools to operate and manage smart low voltage grids (e.g. identification of critical voltage conditions and fault localization).

REFERENCES

[1] TOR Part D2, Technical and organizational rules for network operators and users – part D2; E-Control, 2007.

[2] TOR Part D4, Technical and organizational rules for network operators and users – part D4; Parallel operation of generators connected to the distribution network, E-Control, 2008.

[3] Abart 2009: “Smart Metering Features for managing low voltage distribution grids”; 20th international Conference on Electricity Distribution 2009, paper 0189

[4] Srini Krishnamurthy, 2008, " Smart Grids and AMI: Understanding the Big Picture ", *Proceedings, Grid-Interop Forum 2008*- Paper_Id-4

[5] S.V. Vadari, J. Taft, 2008, " Smart AMI Solutions Enable the Smart Grid ", *Proceedings, Grid-Interop Forum 2008*- Paper_Id-1

[6] Jorge Vasconcelos, 2008, *RSCAS Policy Papers RSCAS PP 2008/01 Survey of Regulatory and Technological Developments concerning Smart metering in the European Union Electricity Market* , Robert Schuhmann Centre for Advance Studies, San Domenico de Fiesole, Italy, ISSN 1830-1541.

[7] T. Tran-Quoc, C. Andrieu, N. Hadjsaid, Technical impacts of small distributed generation units on LV networks, Power Engineering Society General Meeting, 2003, IEEE, DOI 10.1109/PES.2003.1271027