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REEL Demo – Romande Energie ELectric network in local balance Demonstrator

Deliverable: 1c Validation of Model-Less Approach for Estimation of Sensitivity Coefficients

Demo site: Chapelle

Developed by
Sotirios Dimitrakopoulos; DEPsys
Omid Alizadeh-Mousavi; DEPsys
Joël Jaton; DEPsys

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1. Description of deliverable and goal

1.1. Executive summary

The sensitivity coefficients are used in many power system-related analysis and control approaches. They contain important information on the grid's behavior and its characteristics. For instances, the voltage sensitivity coefficients reflect the impact of power change at a particular node on the variations of voltage at all nodes.

The sensitivity coefficient calculation process is an arithmetic procedure of building a matrix of the partial derivatives. This matrix building process requires a prior power flow analysis, by primarily creating an admittance matrix. The requirements for this are grid topology and parameters, including cable resistance, reactance, and susceptance. The typical approach for the calculation of sensitivity coefficients is through an updated Jacobian matrix. The results of Jacobian method is considered as the reference for the calculated sensitivity coefficients of other methods.

The model-less approach for determining the sensitivity coefficients only uses the measurement data and does not require the information of grid parameters. The model-less approach is important for determining the sensitivity coefficients in distribution grids for which often an accurate and up-to-date model of the grid is not available.

This work presents the results for validation of the estimated sensitivity coefficients using model-less approach with reference to the Jacobian method. The tests are performed using GridEye measurements at low voltage grid in Chapelle.

1.2. Research question

The main research question addressed in this work is the evaluation of the performance of the model-less approach for determining the sensitivity coefficients with respect to the Jacobian method. To answer this question, the model-less outputs are directly compared with the expected outputs of the Jacobian method. Since Jacobian method requires the grid parameters, the model-less approach is tested for two different cases, one for the voltages obtained by power flow outputs and one for the measured voltages.

1.3. Novelty of the proposed solutions compared to the state-of-art

There are various methods for the calculation of the sensitivity coefficients for an electrical power grid, such as Jacobian, Gauss-Seidel. The model-less approach is an alternative for determining the sensitivity coefficients, specifically in distribution grids where an accurate and up-to-date information of grid model is not always available. The inaccuracy of the grid model can be due to imperfect knowledge of the grid topology (e.g. frequent changes of topology) and/or inaccurate grid parameters (e.g. aging/damage of infrastructure, neglecting impedance of fuses/joints/connections). Hence, the automatic identification of grid characteristics based on measurements of electrical quantities is very important for many smart grid applications, specifically for those applications with plug and play functionality.

This work presents the results for the validation of the model-less method for determining sensitivity coefficients of an electric power grid according to which knowledge of the grid parameters is not required and only measurement data are used. The model-less method is studied in SMILE project and it is validated in the laboratory environment in SMILE-FA project. In this work, the results of the model-less method are validated using field measurements provided by GridEye in low voltage grid in Chapelle.

1.4. Description

The sensitivity coefficients provide insight about the important characteristics of power grids. They are the partial derivatives describing how the output variable is affected by the input variables. Essentially, it is a measure to show how much the change of an input variable affects the outputs within the same grid. Typically, active and reactive power are the inputs, correlated via a partial derivative with the outputs, which are nodal voltage and branch currents. For instances, the voltage sensitivity coefficients reflect the variations of voltage at a particular node with respect to power variations at all nodes. More specifically, the values of the voltage sensitivity coefficients with respect to active power represents the effect of 1 kW additional active power at a node on all nodal voltages within the same grid. For a grid of N nodes, there is a NxN matrix of sensitivity coefficients, which is comprised of partial derivatives of voltage with respect to powers. The sensitivity coefficient calculation process is an arithmetic procedure of building a matrix of the partial derivatives. This matrix building process requires a prior power flow analysis, by primarily creating an admittance matrix. The requirements for this are grid topology and parameters, including cable resistance, reactance, and susceptance. The typical approach for the calculation of sensitivity coefficients is through an updated Jacobian matrix. The results of Jacobian method is considered as the reference for the calculated sensitivity coefficients of other methods.

The model-less approach determines the sensitivity coefficients only using the measurement data and does not require the information of grid parameters. The model-less approach is important for determining the sensitivity coefficients in distribution grids for which often an accurate and up-to-date model of the grid is not available.

2. Achievement of deliverable:

2.1. Date

The results of this work package are achieved during 2018 and 2019.

2.2. Demonstration of the deliverable

For the model-less evaluation of the quality of supply in LV grids, the voltage sensitivity coefficients are calculated using three different methods, as described below.

Jacobian: calculation of the sensitivity coefficients using the grid model and the voltages obtained from power flow results. Noting that the power flow results are calculated using the measured nodal power injections. The sensitivity coefficients calculated using Jacobian method is considered as the reference and they are calculated for every operating point. In this approach it is assumed that the grid model is accurate and up-to-date.

Model-less power flow: calculation of the sensitivity coefficients using the voltages obtained from the power flow results. Reminding that the power flow results are calculated using the measured nodal power injections. Using the "Model-less power flow" method, only one set of the sensitivity coefficients are calculated for a given duration of measurement data. In this approach it is assumed that an accurate and up-to-date grid model is available.

Model-less measurement: calculation of the sensitivity coefficients using the measured voltages. Using the "Model-less measurement" method, only one set of the sensitivity coefficients are calculated for a given duration of measurement data. The knowledge of the information of grid model is not needed in this approach.

The results of abovementioned methods are used to quantify the errors between the developed algorithm and produce insights, based on the outcomes.

The three methods are used to determine the sensitivity coefficients for the LV grid of Chapelle, shown in Figure 1.

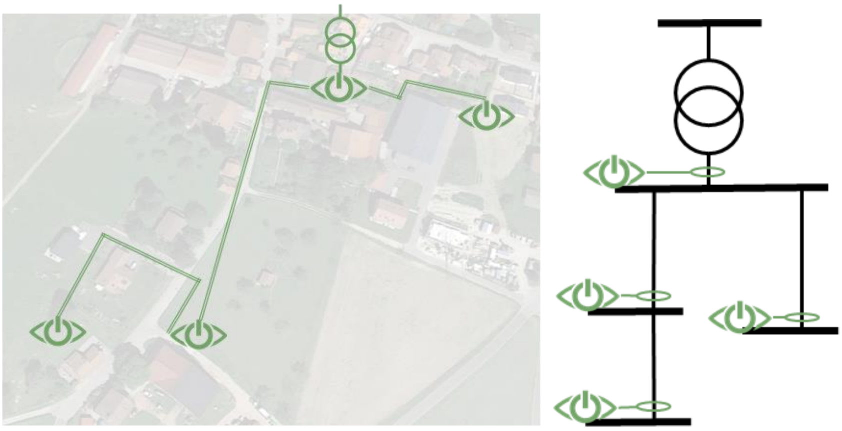

Figure 1. Chapelle LV grid, location of GridEye cells and grid single line diagram.

The calculated voltage sensitivity coefficients using the different methods are presented in Figure 2, where the coefficients are given by K_{vp} in $[V/kW]$. In this grid, there are four measurement points, therefore the calculated mutual sensitivity coefficients are a matrix of 4x4, where each row *i* and column *j* represents the relation between the voltage changes at node *i* in [V] and the power changes at node *j* in [kW]. The outputs of the Jacobian method calculated for every operating point are shown in red. The average value of the Jacobian coefficients is used as the reference for the calculation of +/-10% and +/-50% margins. These margins are shown with the dashed lines. The output of the "Model-less power flow" method is given with the blue dashed-dotted line. The output of the "Model-less measurement" method is given with the green line.

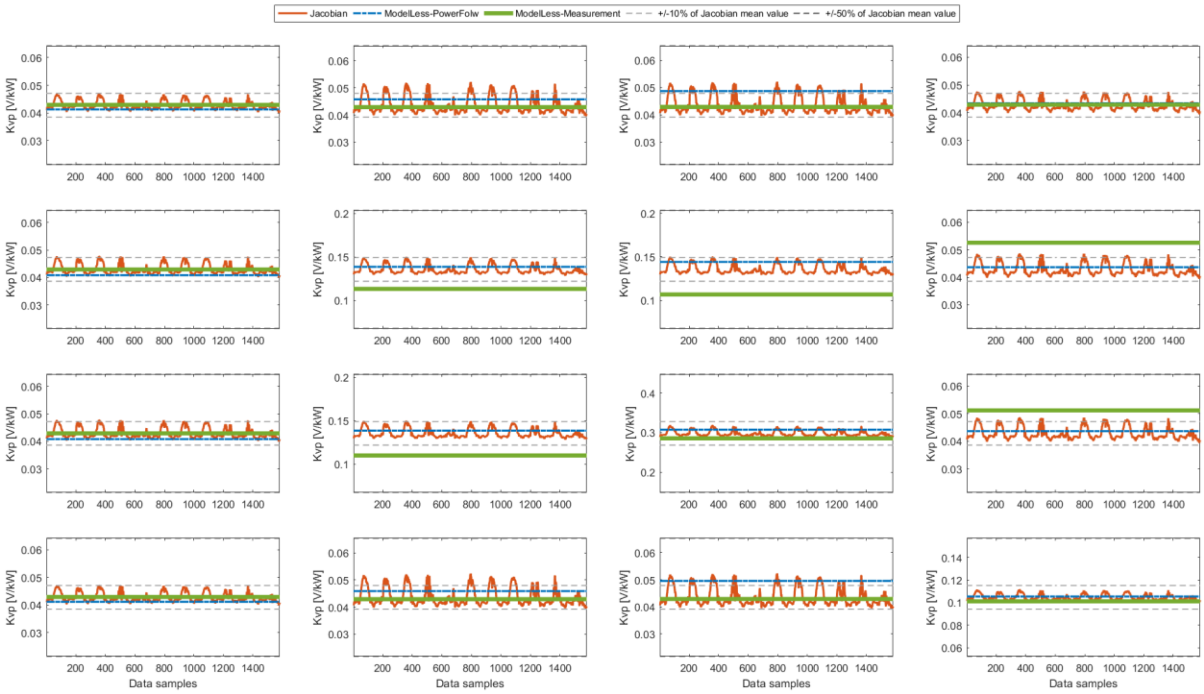

Figure 2. Voltage sensitivity coefficients calculated: (in red) Jacobian method using grid model, (in blue) Model-less power flow method using power flow outputs, (in green) Model-less measurement method using field measurements.

Based on these results, the following observations are derived:

- The variation of the Jacobian sensitivity coefficients is around 10%.
- The "Model-less power flow" method is very close to the average value of the Jacobian method by showing an average 4.6% difference. In some cases, the difference between "Model-less power flow" and "Jacobian average value" reaches to around 10% margin.
- The "Model-less measurement" method is also close to the average value of the Jacobian method by showing an average 7.1% difference. In some cases, the difference between "Model-less measurement" and "Jacobian average value" becomes slightly above 10%. **Noting** that this difference might be due to neglecting the impacts of the fuses/joints/connections impedances and the aging of cables on the grid parameters.

3. Impact

The results of this deliverable are the basis for further activities in work package 2 of REeL demo project related to model-less and decentralized control approach to guarantee the technically secure operation and economically optimal operation of distribution grids.