Assessing the Voltages and Currents in a large Dutch Regional Power Distribution Grid

Werner van Westering*§, Jacco Heres§, Tobias Dekker§, Matthijs Danes§ and Hans Hellendoorn*
*Delft Center of Systems & Control, Delft University of Technology,
Delft, Mekelweg 2 2628CD, The Netherlands
§Alliander N.V., Duiven, Dijkgraaf 4, 6921 RL, The Netherlands

***Abstract*—Modeling low voltage networks poses a challenge to Distribution System Operators (DSOs) because the low voltage networks generally consists of millions of cables. This paper provides a method to model congestion problems and applies this to such a large low voltage network. By modifying the load model of a customer, a linear load flow model was created. Using a custom sparse solver model, all instantaneous currents and voltages were calculated for the network of Liander DSO, containing over 20 million cables and 3 million power customers. The model took only 30 seconds to simulate the entire network. The results shows that the network of Liander DSO can accommodate quite a large number of solar power installations with relative ease. Also, step-change transformers are shown to have quite some potential to solve voltage issues that can arise due to solar power.**

Keywords*—*Distribution grid, Energy transition, Power quality, Voltage problems, Load flow approximations,

I. Introduction

The energy landscape is expected to change significantly in the Netherlands over the next decades, as the share of renewable energy is increasing. This poses a significant challenge for Distribution System Operators (DSOs), which are responsible for maintaining a reliable and affordable electricity distribution grid. Especially the rise of solar power is challenging, as these installations can cause local voltage problems which can be very expensive to solve.

While large scale medium voltage networks have been studied to some extend [1][2], large scale low voltage networks have not had much attention. One of the major uncertainties in low voltage networks is the actual number of problems the solar power installations will cause. This paper provides a method to model congestion problems in very large low voltage networks, which makes it possible to anticipate these problems.

Subject of this study is the Liander DSO low voltage electricity grid. This network operates at 230V (single phase) and connected to higher voltage levels by distribution transformers. Liander DSO is the largest distribution grid operator in the Netherlands with over three million electricity customers.

II. Model assumptions and principles

Conventional load flow models have been around for a long time [3]. However, most load flow solvers are only fit to solve networks up to medium size. Solving the load flow equations for networks with over 1,000 buses is already quite a computational challenge. The Liander network has over 3.1 million buses, making conventional solutions, such as the widely used Newton Raphson method[3], unsuitable.

The model proposed in this paper is a regular load flow model based on Ohms law, but with one major difference in assumption. In conventional load flow modeling, the end users are modeled as requiring a 'constant power load', thus decoupling their energy use from the power grid entirely, as any difference in voltage will not influence the power consumption of the end user.

However, it can be argued that modeling the end users as a 'contstant impedance' load model is at least just as accurately as a 'constant power' load model. In reality, customers will have a mix of devices which require a constant power load, such as home computers and TVs, and devices which are in reality a constant impedance load, such as boilers and heaters.

Modeling all end users as a constant impedance load has a distinct advantage. The load flow equations can be made linear and without iterations. Because of the linear properties of this modified power flow problem, it can be solved for very large networks in a very short time span.

III. Results

All end user voltages in the Liander service area were calculated. Using an custom sparse linear solver and a single core of an Intel Xeon 2.1370 GHz CPU, the network equations Liander network containing over 3 million buses and 20 million cables was solved within 30 seconds.

The Dutch voltage regulations require the end user voltage to be 230V +/- 10%. Figure 1 shows the number of voltage problems in the Liander service area if all customers use 1.1 kW. The number of 1.1 kW was chosen because this is the currently used 'design power' in Liander asset management. However, the 1.1 kW power load is not entirely realistic, since the coincidence-formula's such as Velander [4] were not applied. The transformers were set at 230V. It can be noted that since the model is linear, from which can be concluded that the map of problems due to a *feed-in* of 1.1 kW will look exactly the same.

Table I shows the percentage of voltage problems at customers in the whole Liander service area. All customers are given a certain peak PV power. The 'Voltage' corresponds to the single phase voltage at the secondary side of the transformer.

At a feed-in power 10W, transformer tap setting #1 already results in 100% power problems. This is to be expected,