Project Milestone Report

Microgrid Positioning

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MILESTONE M3.1.

Baseline Distribution System Simulation Model

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01	Ivan Pavić, FER-UNIZG	Final draft

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1. Introduction

Microgrid is a group of small scale facilities which can generate, store or consume electrical energy. The main feature of a microgrid is that all facilities are connected to the same local, usually medium or low voltage grid, which is connected to distribution network through one or more connection points. Location of the connection point within relevant distribution network is very important since it determines distribution network congestions concerning microgrid and flexibility services requirements applicable for microgrid to provide.

This document will describe connection of microgrid to distribution network through several aspects. It will define flexibility services concerning both microgrid and distribution network and compare the distribution network behaviour with transmission network behaviour. Then it will define and explain modelled distribution network used as a test case for our microgrid connection.

2. Transmission vs Distribution Network

Congestions in transmission system and wholesale electricity market can result in generation or demand curtailment since system cannot absorb or transmit all the electricity from the grid users/market participants. In order to prevent curtailment two methods are currently used. The first one is determination of locational market price which leads to different electricity prices within the same market. For example, higher electricity prices in regions where electricity is scarce make generators with higher marginal cost competitive and therefore congestions are resolved. Such method is used in US markets mostly. In EU national markets, if congestions occur then power system operator calls grid reserve to generate electricity in the direction from congested region to rest of the power system. The power generated by grid reserve is paid by all users through network tariffs but the electricity price stays the same in the whole market.

Congestions can be divided to loading and voltage congestions. Loading congestions are caused by power flow higher then rated power of lines or transformers, while voltage congestions are caused by voltage above or below specified voltage boundaries. Both influence natural power flow and prevent grid users to inject or absorb desirable amount of electricity. Transmission system is composed of smaller number but higher rated (power rating) network elements and voltage issues can be easily solved by reactive power injection by large-scale generators or through efficient placement of reactive power provision elements (STATCOM, FACTS…).

Distribution network differs from transmission network in several aspects. It can be defined as a link between transmission network and end-consumers. Electricity must be distributed to each of the individual consumers, therefore distributed network main features are large number of elements, long lines and spatial prevalence. Distribution network, in contrast to meshed transmission network, is of radial character. Due to such features, microgrid's flexibility provision is of high value to distribution network operation and planning.

3. Flexibility Provision in Distribution Network

Flexibility services can be divided into short-term and long-term flexibility. Short-term flexibility is related to distribution system operation, while long-term flexibility is a measure which can be used in distribution system planning, expansion and reliability of supply calculations.

Short-term flexibility can be procured directly from the local distribution market – price signals, or from distribution system operator – grid signals. Price signals form the market means, for example, peak demand shaving in order to lower overall electricity price. On the other hand, grid signal means solving grid issues dynamically, such as voltage violations or distribution transformer overloading.

Long term flexibility provision is distribution network planning considering distribution network users' flexibility into account. Traditional congestion removal methods, or traditional distribution network planning methods, are investment into new network capacities such as lines and transformers. The problem arises when high capital investment is required to solve congestions for small number of customers. Using (reserving) flexibility of distributed energy resources (microgrid is one of them) in long run can deferral or mitigate expensive investments.

4. Distribution system simulation model

In order to properly assess microgrid's behaviour real distribution network will be used. The test distribution system is one of the 21 distribution reginal utilities in Croatia as displayed on Figure 1 (red coloured area). General information about test distribution system model is listed in Table 1. More information can be found in [1].

Figure 1 Croatian regional distribution utilities

Table 1 General inforamation about test distribution system

Surface	1406 km^2
Inhabitants	60.000
Billing metering points	30.000
Annual consumption	210 GWh
Annual electricity loss	4,32%
Peak load	46,32 MW
Feeder supply (110 kV) points	2

Figure 2 shows annual peak demand variations for test distribution system through 10 year period. Figure 3 shows monthly peak demand variations for 110 kV supply feeders through 2 years period.

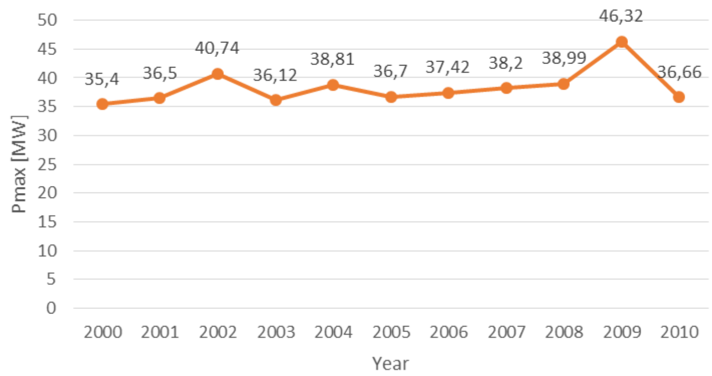

Figure 2 Peak demand through ten years period – whole distribution area

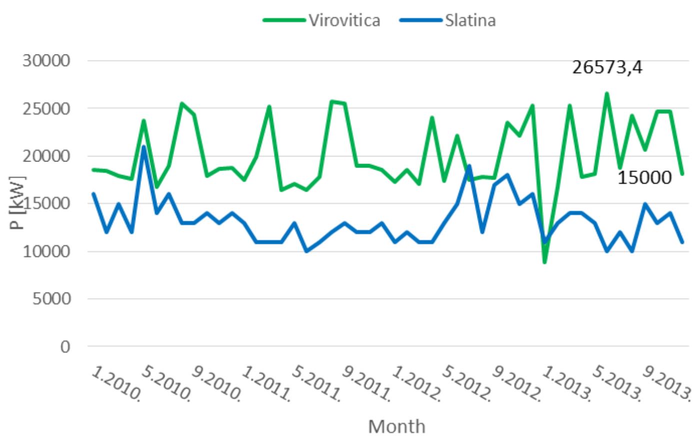

Figure 3 Peak demand through 48 months period – by 110 kV feeder supply

To properly address test distribution system, 110 kV, 35 kV, 10 kV and 0,4 kV level was modeled. Figure 4 shows part of Croatian 110 kV level transmission network. 110 kV level is not part of test distribution system, but connection to transmission network through 110/35 kV substation is important to asses microgrid's impact on transmission system via test distribution system. Feeder supply (110 kV) points are circled in red, while the observed 110/35 kV substation is colored in green. Figure 5 shows modeled 35 kV level where feeder supply (110 kV) points are circled in red. Figure 6 and Figure 7 show modeled 10 kV network colored by 110 kV and 35 kV feeders, respectively.

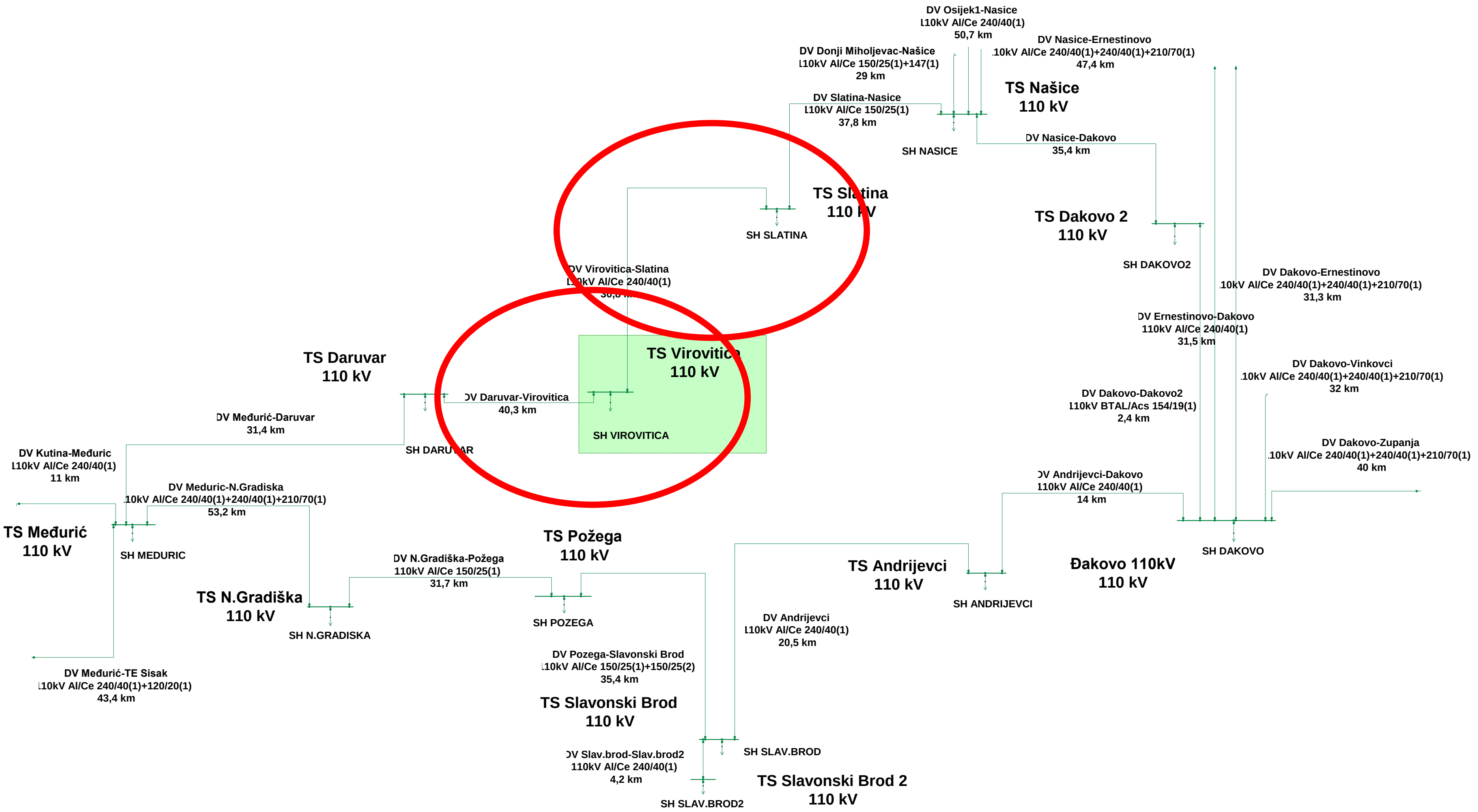

Figure 4 Modeled 110 kV network

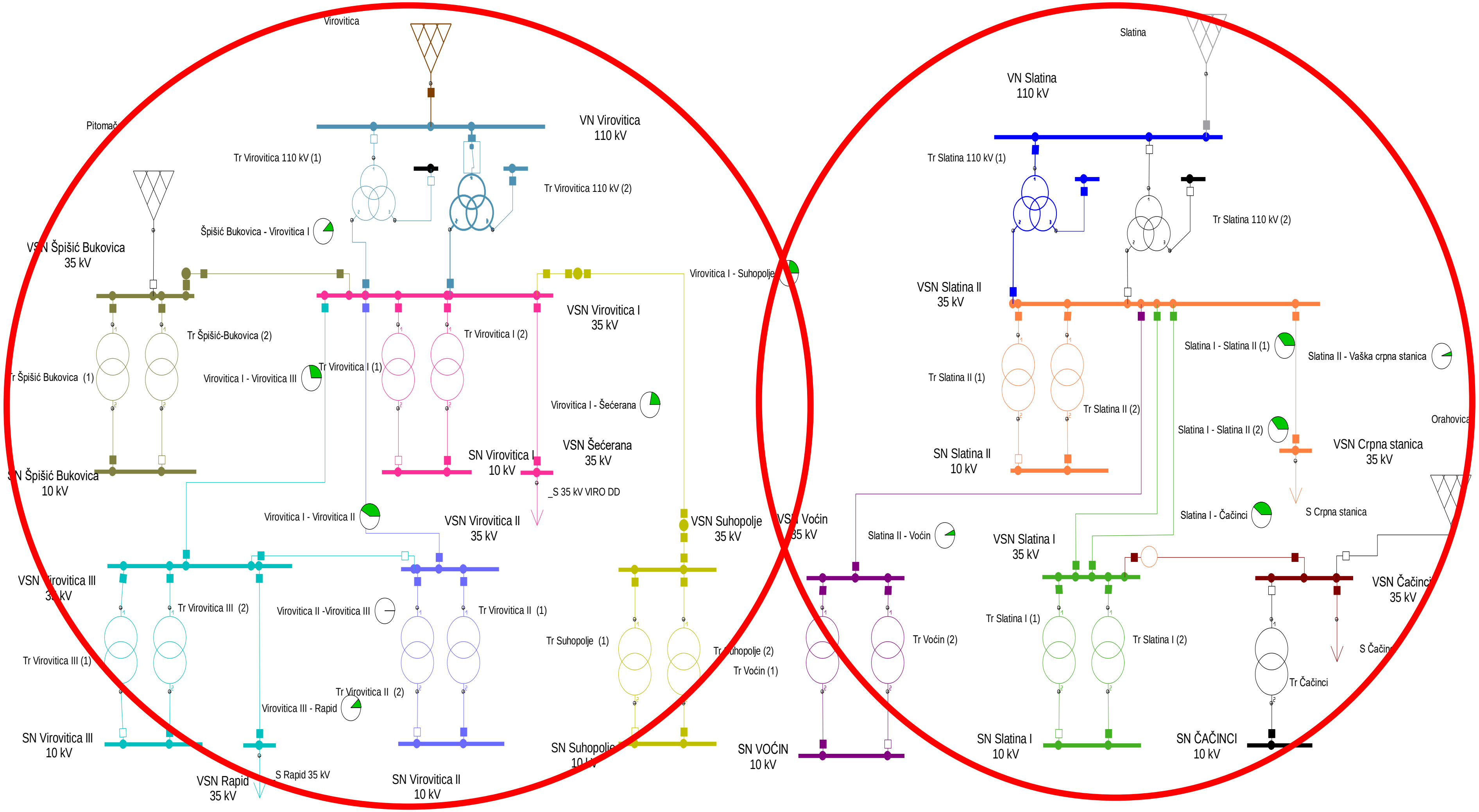

Figure 5 Modled 35 kV network

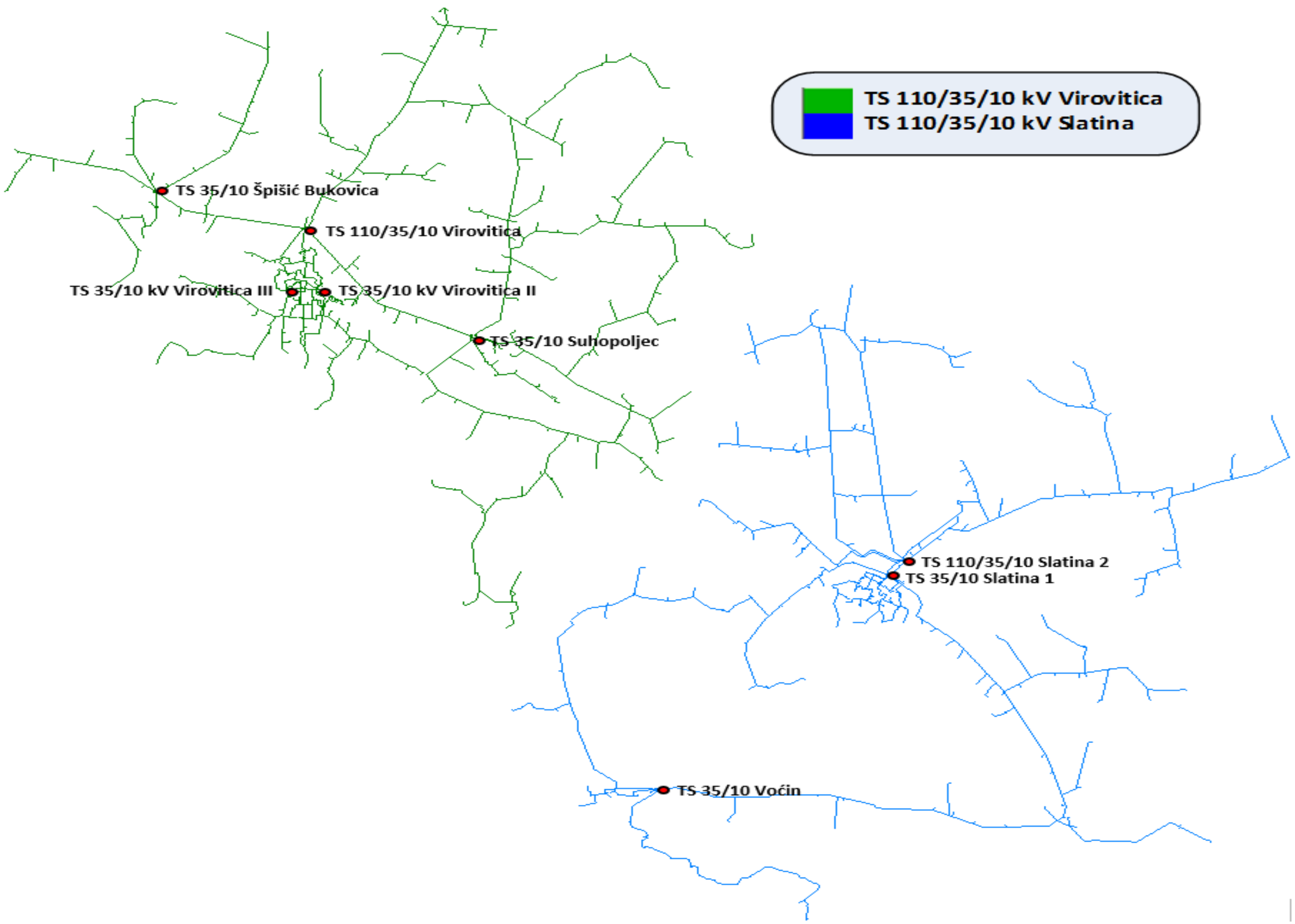

Figure 6 Modeled 10 kV network (110 kV supply feeders)

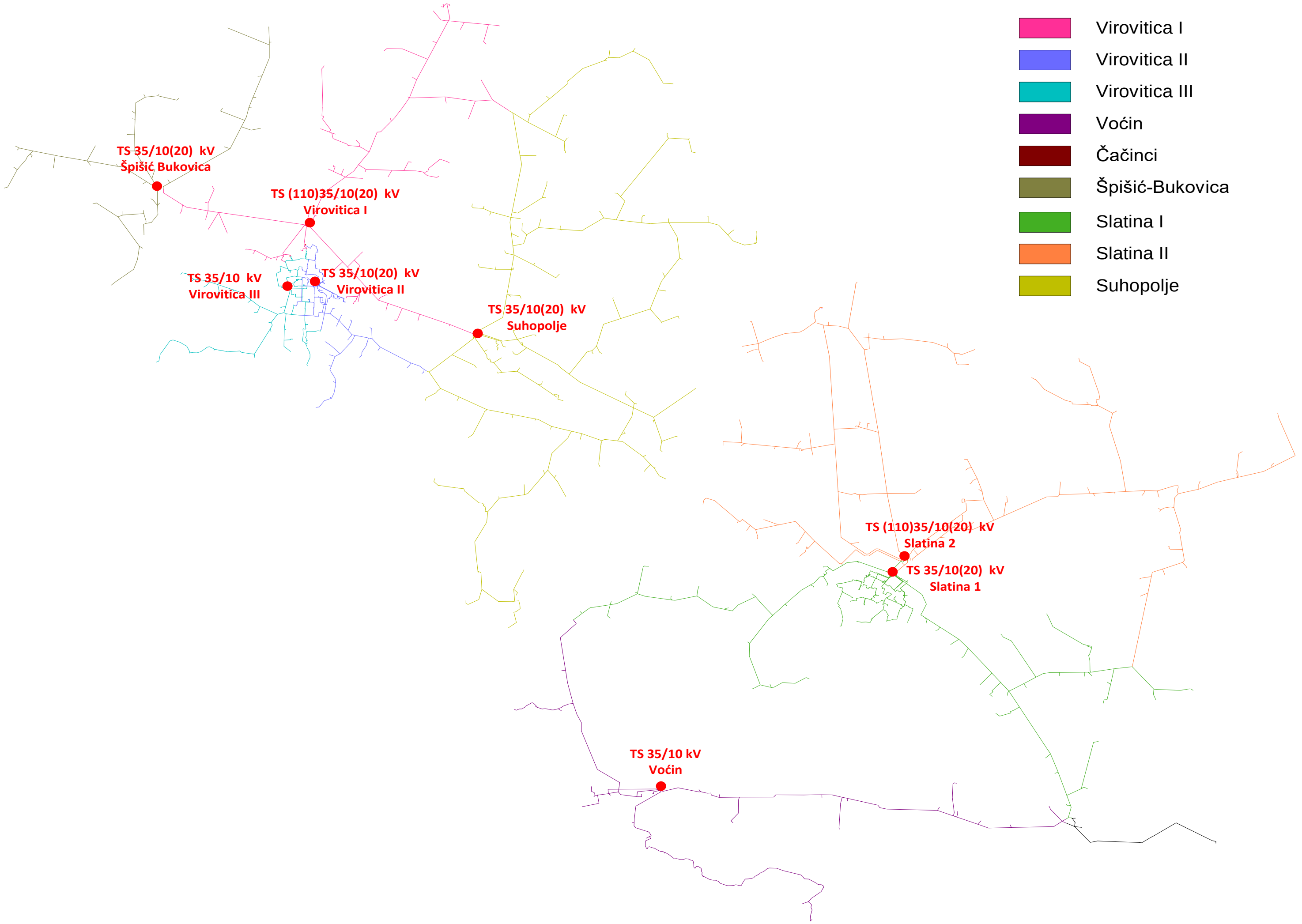

Figure 7 Modeled 10 kV network (35 kV supply feeders)

5. Grid Signals Example

Figure 8 displays distribution network voltage issues. If a microgrid is connected to 10 kV feeders with voltage issues, distribution system operator could send signals for active and reactive power injection to microgrid in order improve grid conditions. For a microgrid it means additional revenue stream.

Traditionally distribution network was unidirectionally supplying low voltage consumers taking electricity from the transmission network. Rapid integration of renewable energy sources into distribution network can cause change in power flow direction from transmission -> distribution (Figure 9) to distribution -> transmission direction (Figure 10). Such change in power flow direction is causing additional needs for investment into power system protection and control equipment. These additional costs can be deferred by flexibility provision of microgrid for appropriate remuneration.

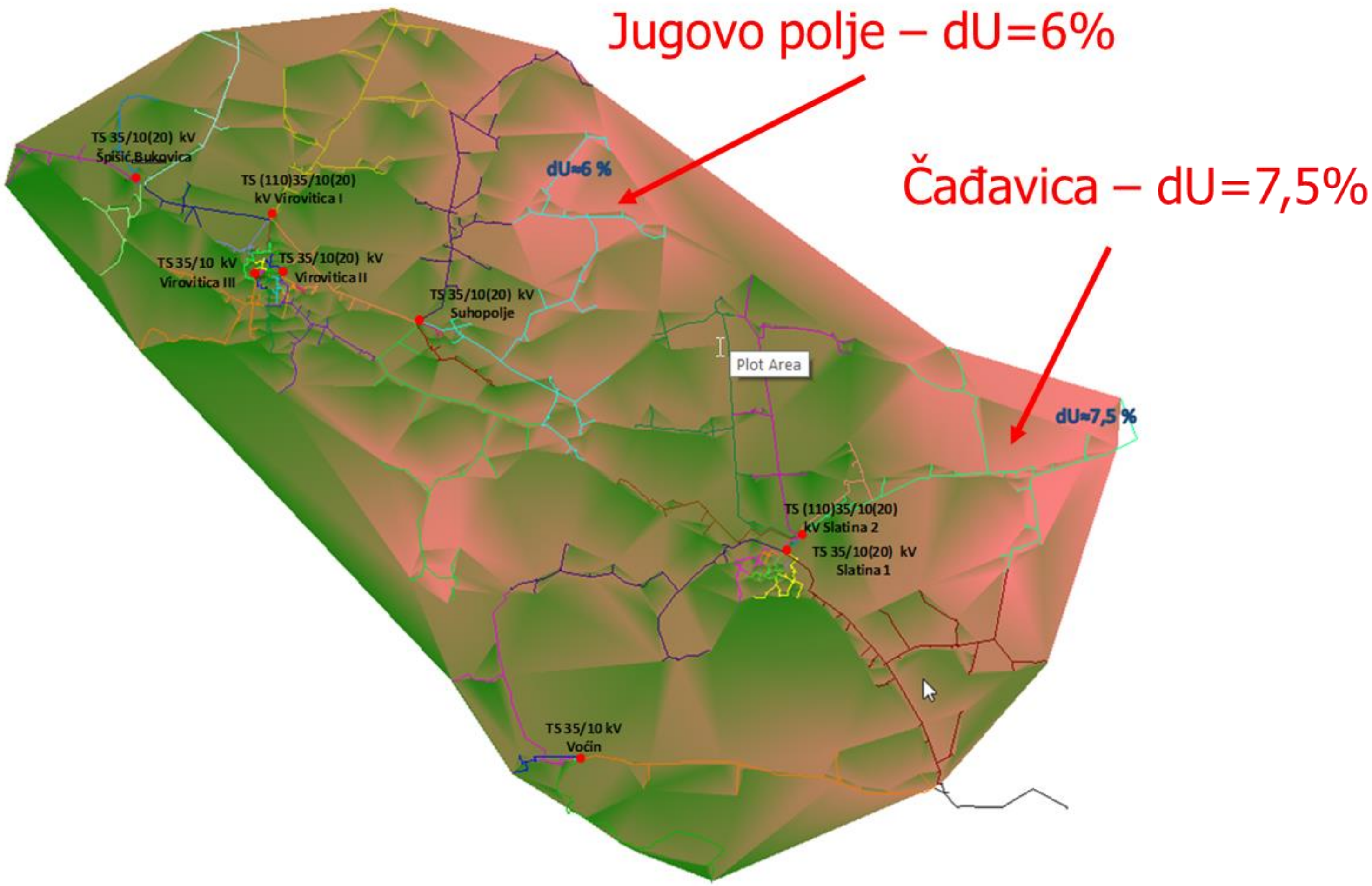

Figure 8 Voltage issues in test distribution system

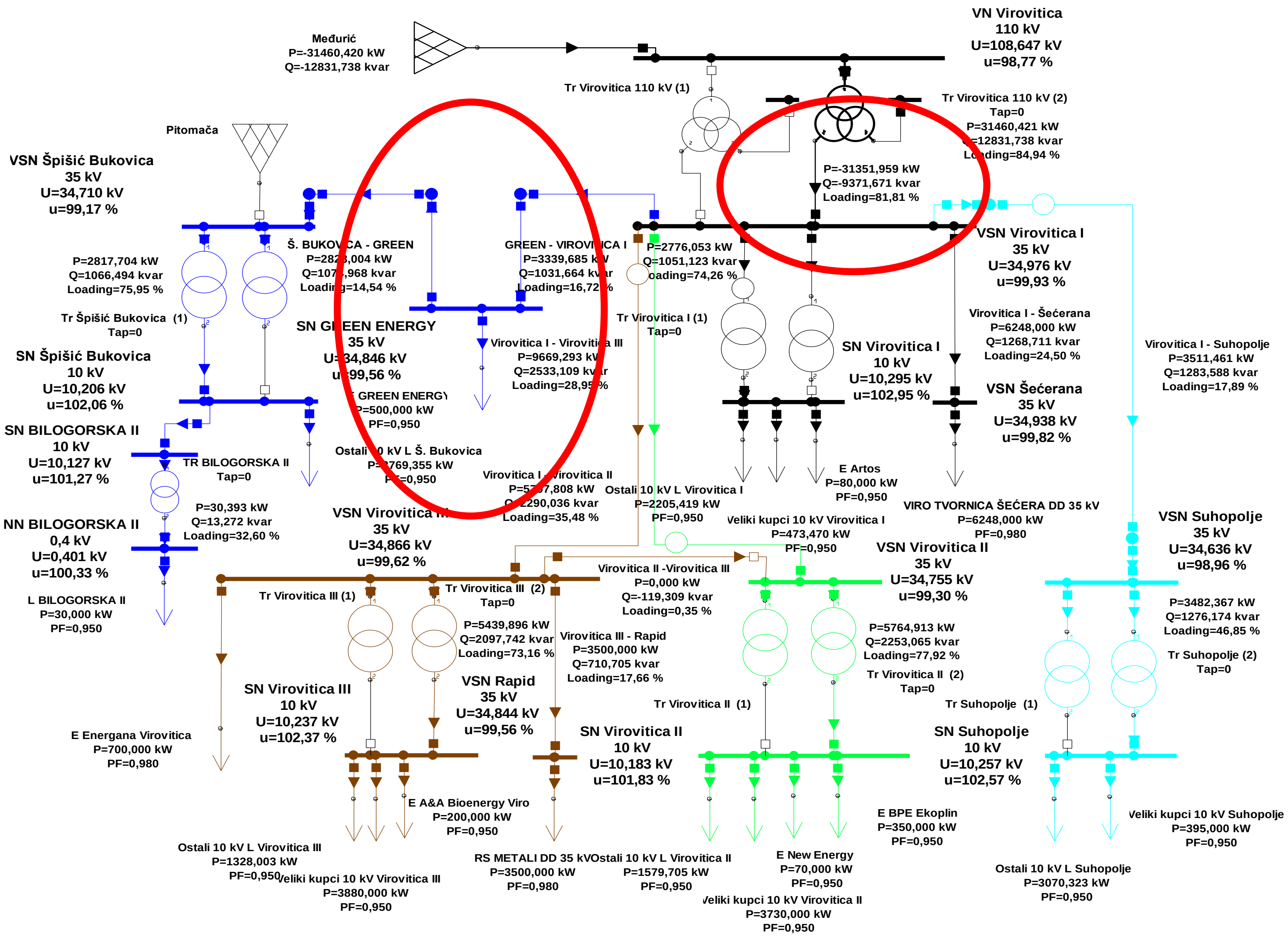

Figure 9 Transmission system supplying distribution network

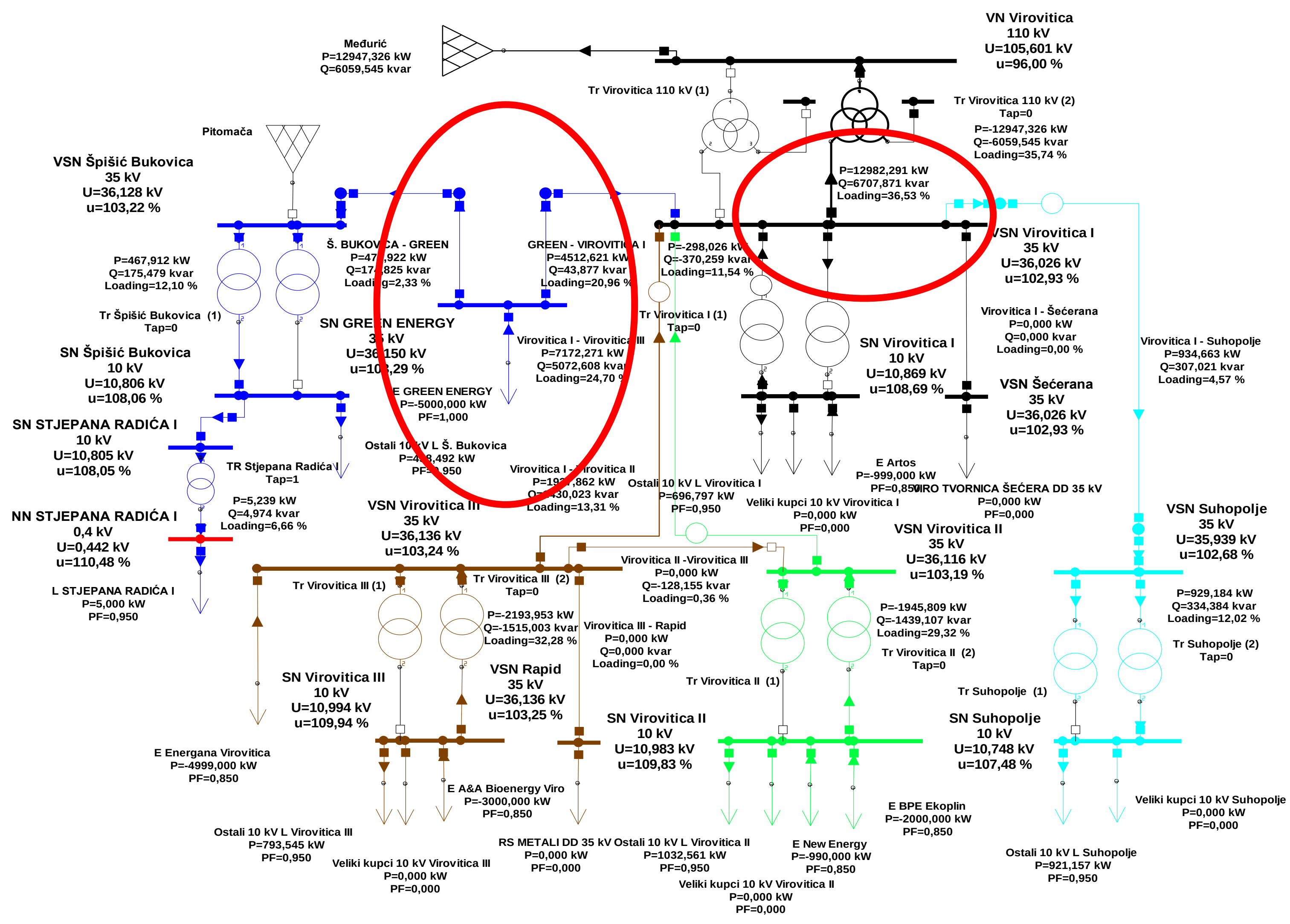

Figure 10 Injection into transmisison system

6. Conclusion

Microgrid, as a local electricity market participant and distribution network user, can earn in few distinctive ways:

- Dynamic electricity price -> electricity market;
- Provision of system ancillary services (reserves) -> transmission system operator;
- Provision of local ancillary services -> distribution system operator
- Provision of congestion removal in distribution network -> distribution system operator;
- Dynamic network tariffs -> distribution system operator;

Bibliography

[1] "HEP ODS - Naslovna." [Online]. Available: http://www.hep.hr/ods/. [Accessed: 28-Feb-2017].