OPTIMISATION PROCEDURE FOR DETERMINATION OF THE OPTIMAL PARALLEL LINES FOR 110KV ELECTRIC POWER DISTRIBUTION SYSTEMS

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Up to date in several power distribution systems there are main power lines without parallel connection between them. In such cases if there is a fault on some of the lines the consumers attached to the faulty line will be left without electricity. In order to avoid line faults if there are parallel lines interconnecting the main lines this problem can be avoided with electric energy redistribution from the healthy lines. When building such parallel lines in power distribution systems several aspects are to be taken into consideration when the exact connection places are to be determined. These aspects include the length of the parallel line, the type of cable required according to the peak energy consumption. This paper presents an optimisation procedure for determination of the optimal parallel line for connection of the main lines in one exemplar electric grid energy distribution system with three main lines.

Keywords: optimization, grid electric load, system modeling

1. INTRODUCTION AND PROBLEM FORMULATION

Today the existing electrical power distribution systems in the big cities in Bulgaria are facing several problems in the present and especially in the future. With decentralization of the electric grid and making it managed by private companies without knowledge for the rest of the grid it's becoming harder to manage certain parts of the grid. There are many uncertainties that come into play that can harm the delivery of electric power to the consumers like fast addition of many new consumers in certain branches, increased probability for faults due to terrorist acts sabotage or by faults in the grid itself, as it is quite old. With the deregulation for the private electrical distribution companies several main 110KV transmission lines appear as connected in serial with no option to transfer energy from one to another in case of faults in certain parts of the grid. This can lead to lack of electrical energy supply, which is not acceptable in the 21st century. The solution – an multicriterial optimization procedure for determination of the optimal parallel line for connection of the main lines in one exemplar electric grid energy distribution system.

In this paper we present an method for determination of the best spots for creation of parallel lines in the existing grid, that will connect the main distribution line in a way that despite some of the sources is being cut from the grid, the distribution grid can be powered from the other sources. The best parallel reserve line connection spots are determined with optimization procedure by obtaining the minimal line length and minimal current going though the parallel line, while checking if the parts of the existing grid will be able to hold on increased power flow. This is having an impact on the money invested in the parallel lines, as minimal distance means less cable length used, and minimal currents means that the cable requirements will be lessened meaning that cheaper cable type can be used.

One example is done in a power grid in Sofia and the data we have been provided to work with involves three serial 110kV distribution lines without parallel connection between them. Each line has many transformer stations for voltage reduction from 110 to 22kV. Unfortunately the data provided from the electric distribution company is confidential, resulting that the gps coordinates, energy consumption, peak currents, cable types, transformer station parameters and the other parameters used in the optimization procedure are not to be published, and that only partial general results can be given.

2. MODELING AND SIMULATION OF THE ELECTRIC GRID

For modeling the electric grid we used MATLAB. In this development environment in contrast to tools like PSpice there is a lot of freedom for circuit generation and parameter tune. We used a voltage potential method with functions to easily create the conductivity matrix of the grid by applying the conductance between two nodes. From the problem formulation we have several power distribution systems in which there are main power lines without parallel connection between them. In such cases if there is a fault on some of the lines the end result is that consumers attached to the faulty line will be left without electricity and in order to avoid line faults and increase reliability if there are parallel lines interconnecting the main lines this problem can be avoided with electric energy redistribution from the healthy lines. The grid taken into account is shown on Figure 1.

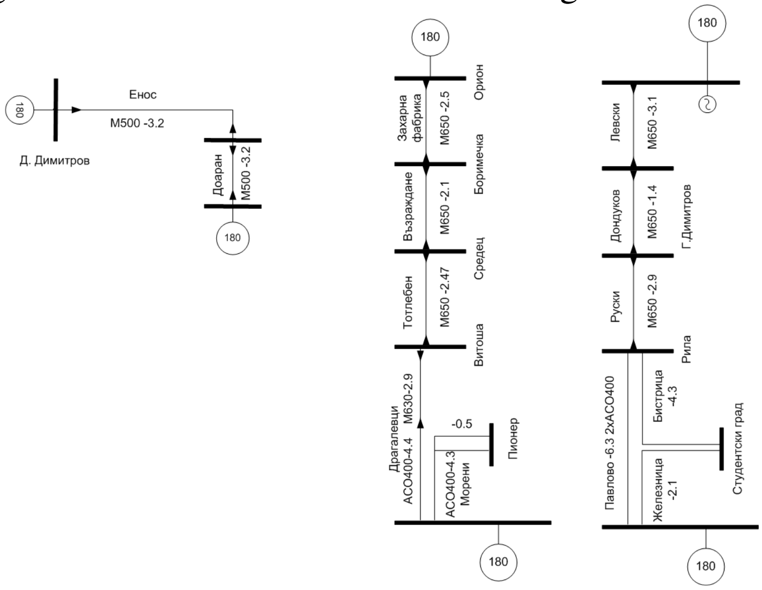

Figure 1. The three main 110kV lines with transformer stations

When building the parallel lines in power distribution systems several aspects are to be taken into consideration when the exact connection places are to be determined.

These aspects include:

-The power supply system – nominal Voltage, nominal Frequency, Short circuit power, X/R ratio

-cable line parameters – specific resistance and inductance per km

-linear conventional loads – nominal active and reactive power

-the length of the parallel line (if it's bigger it will be expensive)
-the type of cable required according to the peak energy consumption.
-capability of the existing infrastructure to handle the loads

As already mentioned there are three serial 110 KV independent lines and each of the serial line consists of Voltage Transformers from 110KV to 22KV for distribution of electric energy for domestic needs. For simplicity the transformer stations with the exception of the endpoint stations are considered as an consumer. The line endpoint voltage transformer stations are connected to high power transmission lines and can deliver enough power to all of the consumers of entire line if needed (if the infrastructure can handle the load). Distances of the existing cable connections and cable types between the stations are known, and also the GPS coordinates on every single transfomer station are known. By knowing the distance between the transformer stations and the cable type used the cable length can be modeled with cable resistance and cable inductivity per kilometer. From catalogue data per kilometer cable Resistance is 0.06 Ohm and the inductance is 0.4H. The distances considered are very small so modeling line capacitive behavior from line to ground is very small and will not be considered.

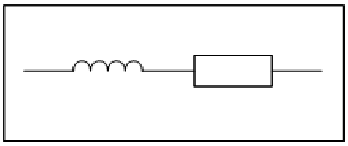

Figure 2. Cable line modeling with 0.06 Ohm and 0.4H per km line length

The consumers are modeled with R and L according to the data for the consumed power. For domestic energy distribution cosf=0.9

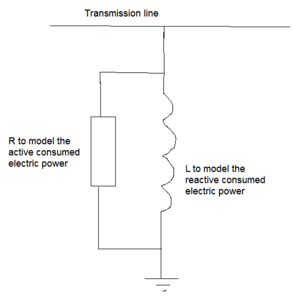

Figure 3. Modeling the transformers as consumers

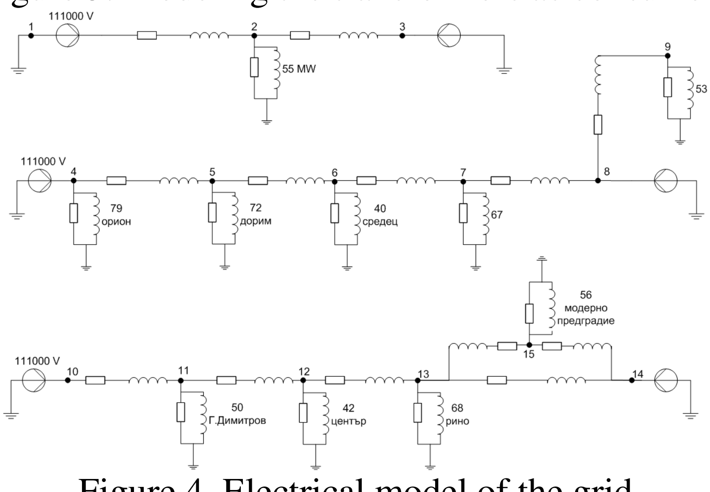

Figure 4. Electrical model of the grid

A program code in MATLAB is generated that makes a electric grid bias point calculation. Then this code is inserted in a loop cycle where the sources are independently removed one by one for every possible combination of the parallel lines. Monitored are the peak currents passing through the transformer stations and the cable distance is calculated with the usage of GPS coordinates. With this calculated cable distance the parallel cable line R and L are also inserted into the model. This results in a various grid combinations as shown on Figure 5.

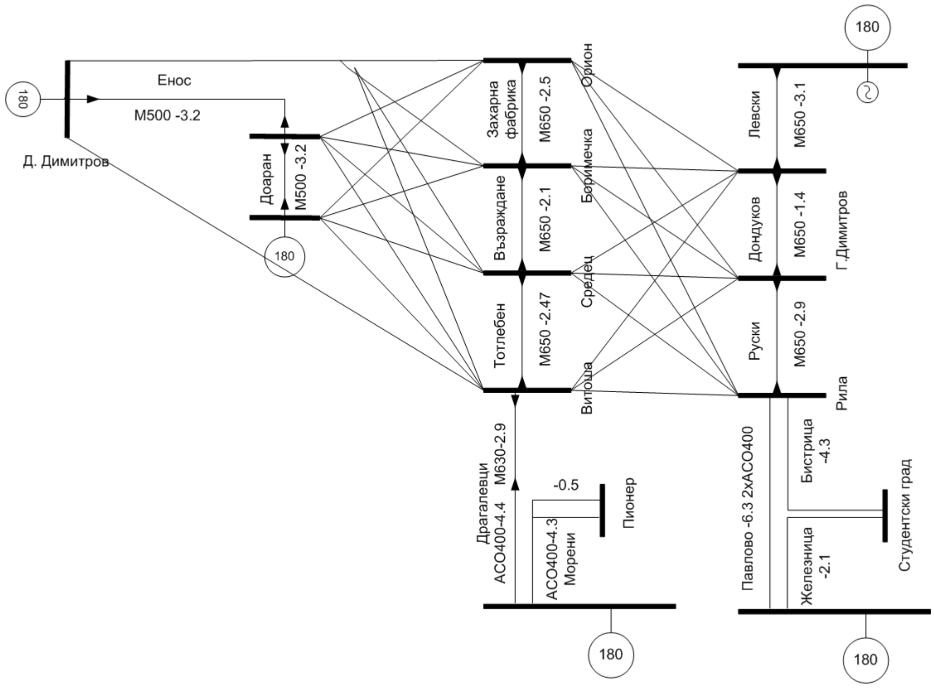

Figure 5. The grid with some of the possible solutions

The best solution is to have a fulfillment of infrastructure endurance on peak currents that are lesser than the maximal by cable specifications of the existing infrastructure while having the minimal distance in km between the new lines.

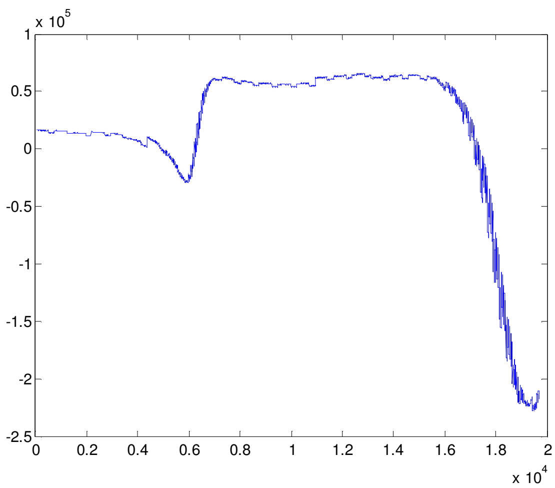

Figure 6. Current variation trough one node for many grid stricture variations

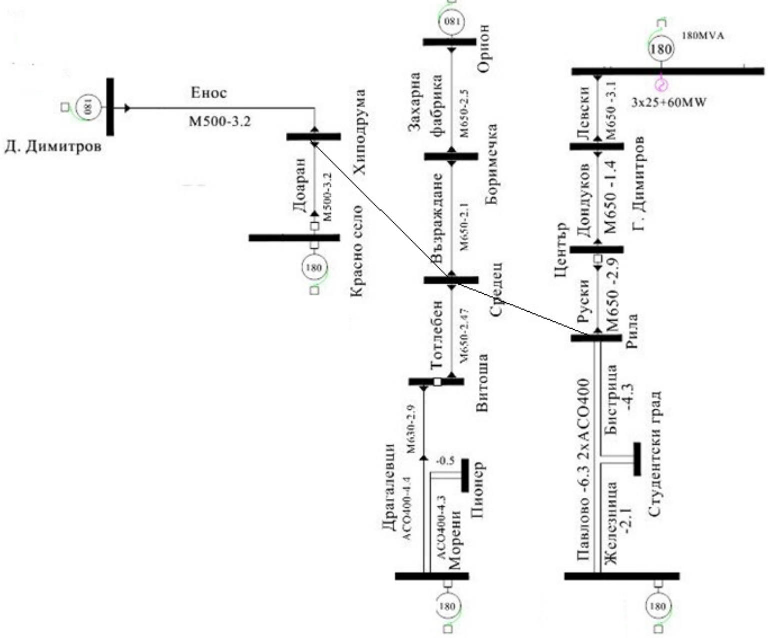

Figure 7. The best solution for the parallel lines

3. CONCLUSION

With computational algorithms the optimal places for placement of parallel lines in existing electric grids can easily be determined with respect to minimal line costs and acceptable minimal peak power transfer from the infrastructure.

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