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ОПТИМИЗАЦИОННА ПРОЦЕДУРА С РАЗШИРЕНО МОДЕЛИРАНЕ, ВКЛЮЧВАЩО И КАПАЦИТЕТИТЕ НА ЛИНИИТЕ ЗА ОПРЕДЕЛЯНЕ ЛОКАЦИЯТА НА ОПТИМАЛНИ РЕЗЕРВИРАЩИ ПАРАЛЕЛНИ ЛИНИИ ПРИ ЕЛЕКТРОРАЗПРЕДЕЛИТЕЛНИТЕ МРЕЖИ

Румен Йорданов, Георги Комсалов, Георги Ценов, Валери Младенов

Резюме: *В електроразпределителните мрежи за високо напрежение понякога има главни електропроводи без изградени паралелни връзки между тях. При възникване на проблем с някои от главните електропроводи консуматорите свързани към него ще останат без електричество. Такива проблеми биха могли да бъдат избегнати при наличие на паралелни линии свързващи главните електропроводи с преразпределение на електрическа енергия от единия към другия. При изграждането на такива паралелни връзки са важни аспекти като дължина на линията, типа на кабела, според пиковата консумация и др. В тази статия е показана оптимизационна процедура за определяне на такива връзки при реална дистрибуторска мрежа с три главни електропровода, при моделиране с концентрирани параметри и отчитане на капацитиваностите.*

Ключови думи: *оптимизация, електрически товари, моделиране на системи*

EXTENDED OPTIMIZATION PROCEDURE FOR DETERMINATION OF THE OPTIMAL PARALLEL LINES FOR ELECTRIC POWER DISTRIBUTION SYSTEMS WITH LINE CAPACITANCES MODELING

Rumen Yordanov, Georgi Komsalov, Georgi Tsenov, Valeri Mladenov

Abstract: *In the electric energy distribution system operator networks for some power distribution systems there are main power lines without parallel connection between them. If there is a incident occurring as a fault on some of the main lines, the consumers attached to the faulty line will be left without electricity. We can avoid line faults if there are parallel lines, that interconnects the main lines and this problem can be avoided with electric energy redistribution from the healthy lines. When such a parallel lines are traced in power distribution systems there are several aspects to be taken into consideration when the exact connection places are to be determined like the length of the parallel line, the type of cable required according to the peak energy consumption and etc. In this paper is presented an optimization procedure for determination of the optimal parallel lines for interconnection of the main power lines in one exemplar electric grid energy distribution system with three main lines, taking line parameters to be lumped and taking into account the effect on line capacitances.*

Keywords: *optimization, grid electric load, system modeling*

1. Introduction and problem formulation

Up to date several of the existing electrical power distribution systems in the big cities in Bulgaria are facing problems with electric power distribution line infrastructure. These problems are present today and will be eminent in the future if the infrastructure is left as is. With decentralization of the electric power grid in Bulgaria and making it managed locally by private companies like CEZ, EVN and EON, there is usually a lack of knowledge for the rest of the grid in the country and it's becoming harder for the operators 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 areas, without notification or plan. This lead to increased probability for faults because without planning, the infrastructure in this area is not updated and the peak distribution maximum of the electric power is easily reached, leading to poor quality of the delivered electricity. On the other hand, many parts of the electric distribution infrastructure are quite old, and without parallel connections between them, leading that the electric grid is very vulnerable to terrorist acts, sabotage or naturally occurring faults in the grid itself, because of it's age [1], [2]. With the deregulation for the private electrical distribution companies in Sofia several main 110KV transmission lines appear as connected in serial for the energy distributor CEZ, 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 is to build and parallel line that connect the main 110KV cables. In this case is some of the main line fails somewhere on the external connections, the consumers attached to this line in the city will still have electricity delivered to them, as electric energy will be redistributed and supplied from the healthy lines. But there is a problem with finding the optimal spot for this parallel line in the grid as there are different substations with different cable types and with different topology position. Certainly, the best solution will be to have a connection between substations from the path of the serial line, that will be able to hold the redistribution current and by using the shortest cable possible. A solution to finding the optimal route for the parallel lines is with a multicriterial optimization procedure. With it we can determine the optimal parallel line route for connection of the main lines in one exemplar electric grid energy distribution system [3], [4], [5], [6].

In this paper we present an method for determination of the best spots for creation of parallel lines in one 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 trough 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 performed on a dataset containing the 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 as shown on the map in Figure 1.

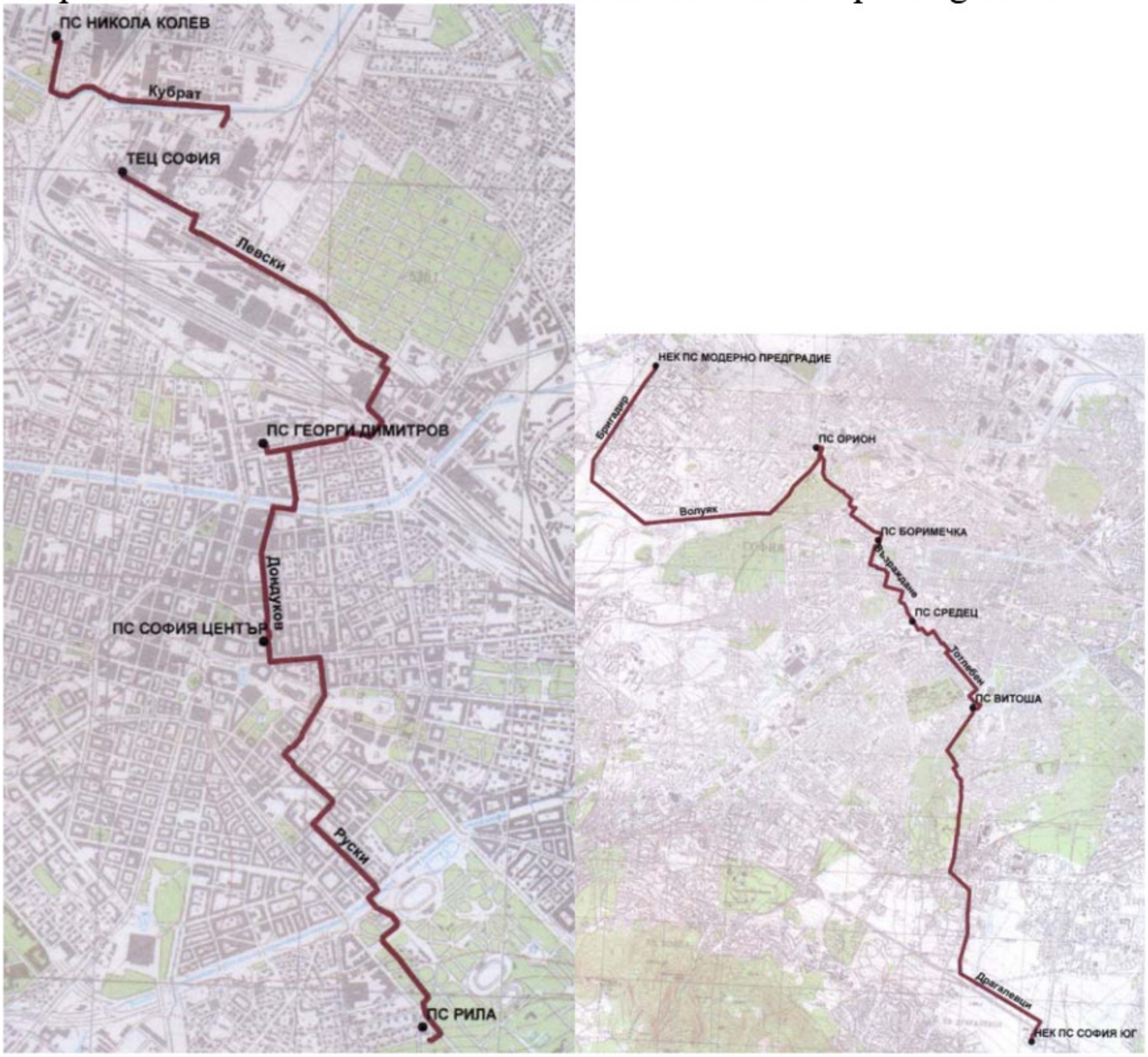

Figure 1. The three main 110kV lines in Sofia on topological map (with red)

Each line has many transformer stations for voltage reduction from 110 to 22kV. The data provided from the electric distribution company CEZ is confidential to the operator, 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 and description on the procedure can be given.

2. Modeling and simulation of the electric grid

For modeling of the electric power grid we used MATLAB. In this development environment, in contrast to specialized tools like Pspice, there is a lot of freedom for grid modeling and individual parameter tune. We used the voltage potential method with user created functions to easily create the conductivity matrix of the grid by applying the conductance between two nodes by having the topology. 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. 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 model taken into account is shown on Figure 2.

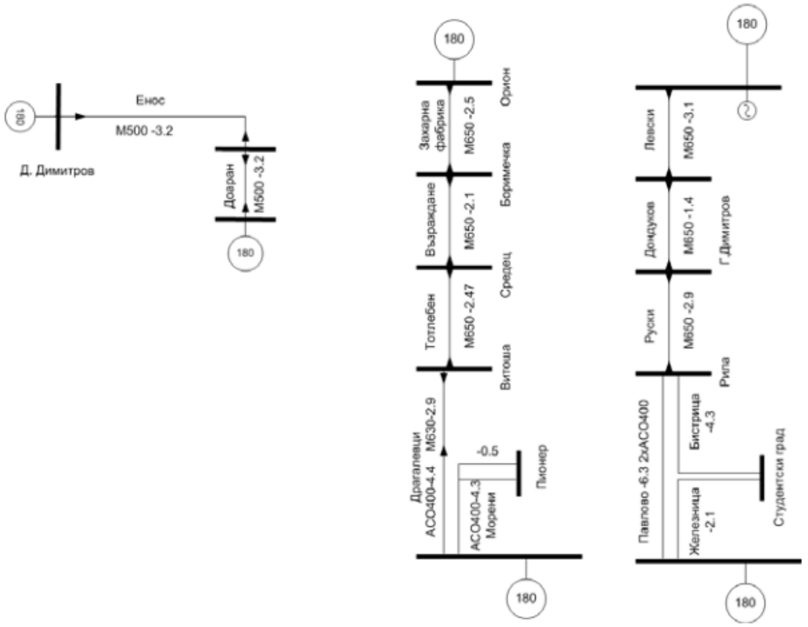

Figure 2. The three main 110KV lines with transformer stations and cable type/length

When tracing 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 reduction transformers from 110KV to 22KV for distribution of electric energy to the 22KV to 220V substations. For simplicity the transformer stations with the exception of the endpoint stations are considered and modeled as consumer. We assume that the line endpoint voltage transformer stations are connected to some high power transmission lines that can deliver enough electric power to all of the consumers of entire line if needed, if the distribution infrastructure can handle the load. Distances of the existing cable connections and cable types between the stations are provided, and also the GPS coordinates on every single transfomer station is given. This provides us with the option that by knowing the distance between the transformer stations and the cable type used the cable length can be modeled with cable resistance and cable inductance per kilometer. We also model the capacitance between the cable and the ground with 0.033μF per km. From catalogue data per kilometer cable Resistance is 0.06 Ohm and the inductance is 0.4H as shown on Figure 3. The distances considered are very small so modeling line capacitive behavior from line to ground is very small and will not be considered.

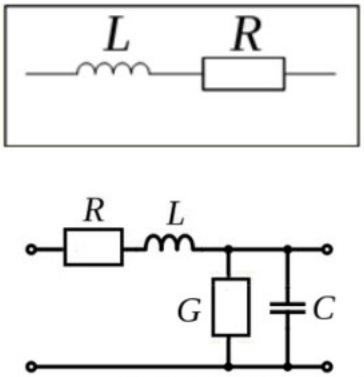

Figure 3. Cable line modeling with 0.06 Ohm and 0.4H per km line length

The consumers are modeled with R and L according to the data for the consumed power as shown on Figure 4. For domestic energy distribution cosφ=0.9

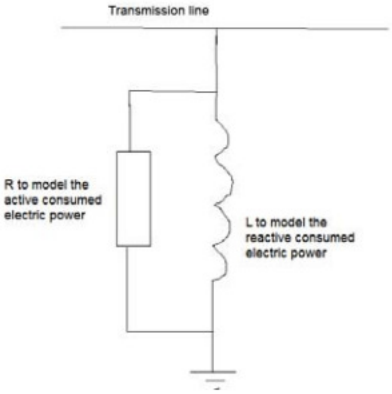

Figure 4. Modeling the transformers as consumers

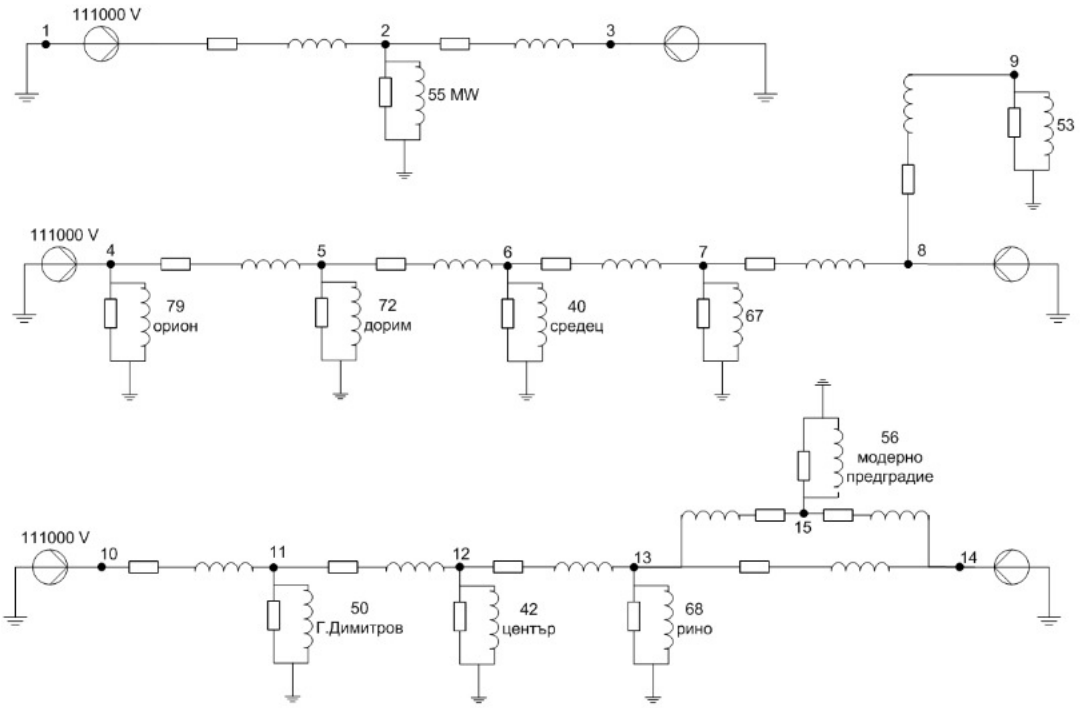

Figure 5. Electrical model of the grid

A program code in MATLAB is generated that makes a electric grid bias point calculation. Then this code is inserted in a chain of for loop cycles 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 6 and Figure 7.

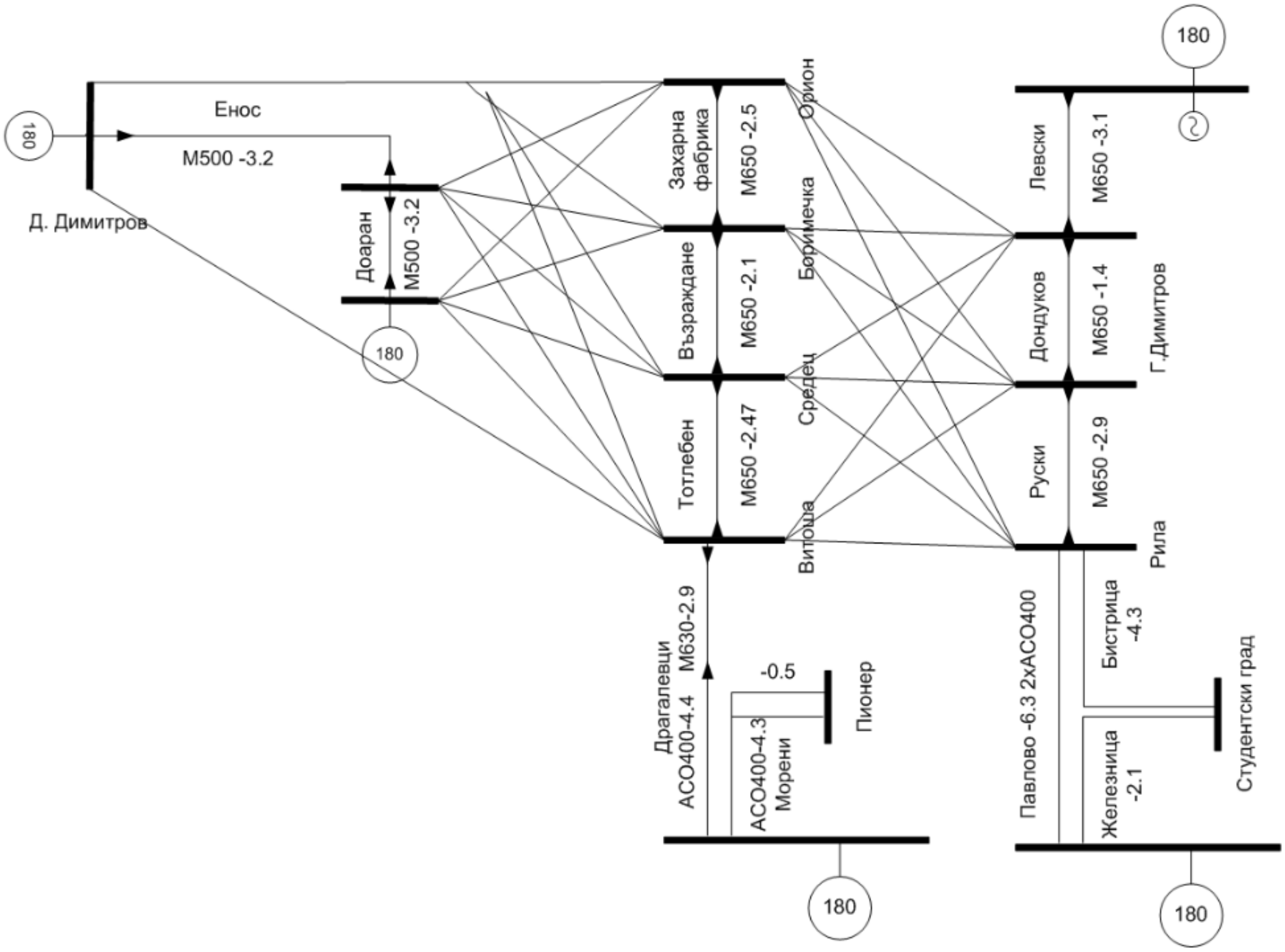

Figure 6. The resulting electric grid with some of the possible solutions

When the electric grid is simulated for all of the possible combinations of the grid structure the best solution is taken with the fulfillment of several criteria. First, the resulting data point combinations for which the currents passing through existing infrastructure lines are bigger than the maximal by cable specifications for this existing infrastructure line are omitted. We don't want to change the existing infrastructure as it will be even more expensive task. So, from all of the existing data points with rotation of the voltage sources we leave the data points for which the existing infrastructure will be able to hold the higher redistributed load. Then, from those combinations of the parallel lines, for which the infrastructure holds, we choose the minimum cable lengths. This lead us to the best parallel line solution taken in respect to preservation of the existing infrastructure and addition of minimal resource when building new infrastructure. The final obtained result from this procedure is shown on Figure 8.

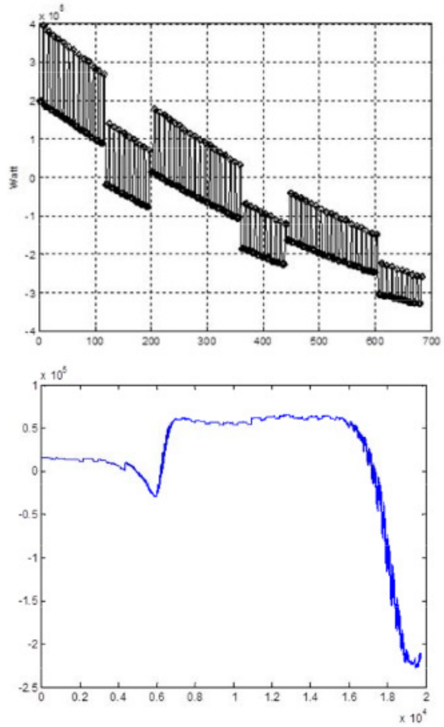

Figure 7. Electric Power distribution variation trough one node for many grid stricture variations for two different nodes for different display points

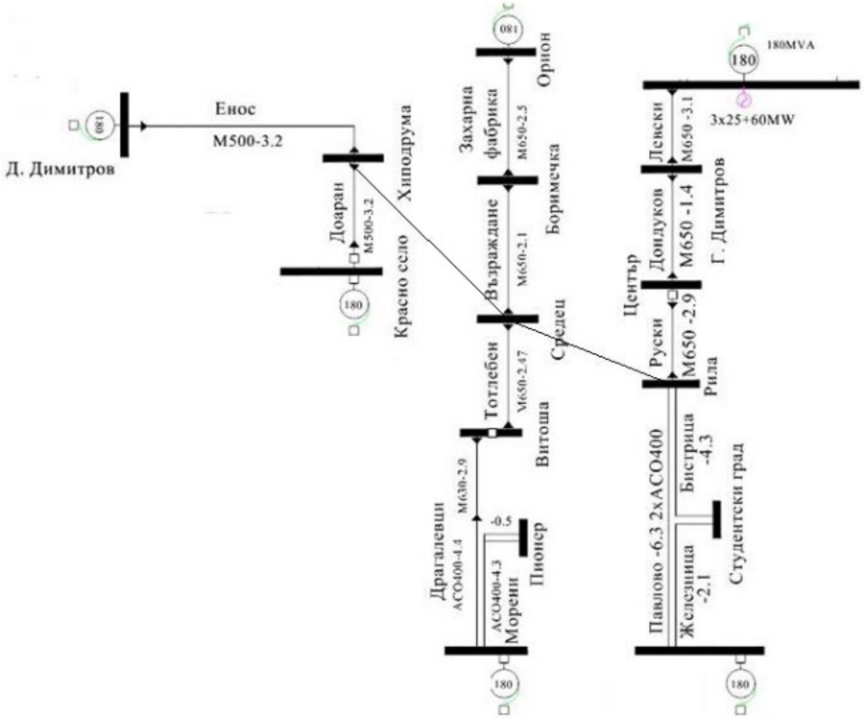

Figure 8. The best solution for the parallel lines in respect to resource minimization

3. Conclusion

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

БЛАГОДАРНОСТИ

Научните изследвания, резултатите от които са представени в настоящата публикация, са финансирани от вътрешния конкурс на ТУ – София със съдействието на НИС на ТУ - София, предложение за финансиране на научноизследователски проекти в помощ на докторанти на тема: “Геометрична многокритериална оптимизация на мрежи за високо напрежение с цел постигане на по-добър резерв на устойчивост, при аварии, при използване на ограничен ресурс”, сесия 2012 - 2013 г.

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Автори:

Румен Йорданов, гл.ас. д-р – катедра „Микроелектроника”, ФЕТТ, Технически Университет - София, E-mail address: *rsyordanov@yahoo.com* ;

Георги Комсалов, докторант, маг.инж. - катедра „Теоретична електротехника”, Факултет Автоматика, Технически Университет - София, E-mail address: *gkomsalov@gmail.com ;*

Георги Ценов, гл. ас. д-р - катедра „Теоретична електротехника”, Факултет Автоматика, Технически Университет - София, E-mail address: *gogotzenov@tu-sofia.bg* ;

Валери Младенов, проф. д-р - катедра „Теоретична електротехника”, Факултет Автоматика, Технически Университет - София, E-mail address: *valerim@tu-sofia.bg* .

Постъпила на 16.05.2013 **Рецензент:** доц. д-р С. Терзиева