MEĐUNARODNO REGIONALNO SAVETOVANJE O ELEKTRODISTRIBUTIVNIM MREŽAMA

REGIONAL CONFERENCE AND EXHIBITION ON ELECTRICITY DISTRIBUTION

Crna Gora, Herceg Novi, 5 - 8. oktobar 2004. / ***Montenegro, Herceg Novi, October 5 - 8, 2004***
* *

SOFTWARE SOLUTION FOR FAULT EVALUATION AND ITS APPLICATION TO RELAY PROTECTION SETTINGS

A. Rasic - Institute of El. Engineering "Nikola Tesla" – Belgrade; Serbia and Montenegro *
G. Djukic – Faculty of El. Engineering – Belgrade; Serbia and Montenegro **

ABSTRACT

Demands for efficient and detailed calculation of short circuit currents are presented today for effective use of all possibilities brought by actual microprocessor protection systems from the side of their sensitivity and reliability. In this paper it's presented a short presentation to software pack which enables elegant analyze of faults from the point of calculation of characteristic current and voltage values. The detailed calculation is provided on a base of Ybus matrix, which is good starting point because contains all the necessary data needed for calculation. Starting from Ybus matrix and from network equivalent (distribution as well as transmission), and from adequate fault model, it's been led to relevant template for software solution. With presented software solution, together with needful training in software use, it is possible to solve any situation with fault in the analyzed network and to get relevant values of the currents and voltages on the place where the relay is been installed.

1. TEMPLATES FOR REALISATION OF SOFTWARE SOLUTION

The power systems structure could be loop (as a rule at Transmission network) or radial (Distribution network). For the analyze of the any kind of network, there is a need for providing a great number of different calculations. For that needs, the most efficient way is to make equivalent of the starting network from the point of view of the element where the protection is analyzed. That equivalent is described with less number of equations which are faster to solve lots of number of times.

1.1 Network equivalents

The complex transmission network, for the needs of relay protection, on one detached element, is displayed on figure 1(Element between nodes 1 and 2 where the protection has been analyzed).

**Institute "Nikola Tesla" ; Koste Glavinica 8 a ; Belgrade ; Serbia and Montenegro*
***Faculty of El. Engineering* ; *Bul. Kralja Aleksandra 73; Belgrade; Serbia and Montenegro*

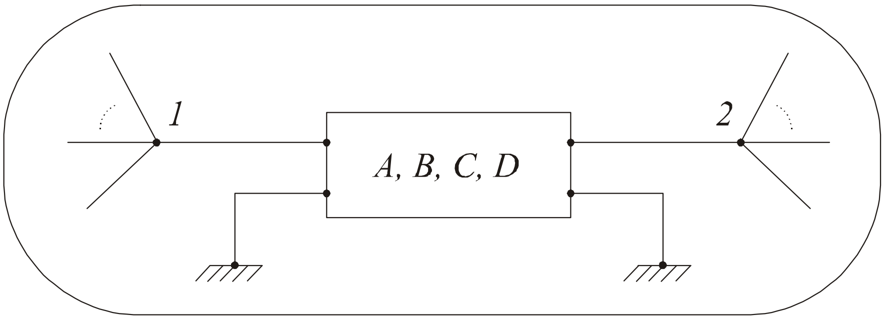

Figure 1: *Transmission network with the observed element with parameters A, B, C, D*

The complex transmission network, for the needs of relay protection, on one detached element, is displayed on figure 1(Element between nodes 1 and 2 where the protection has been analyzed).

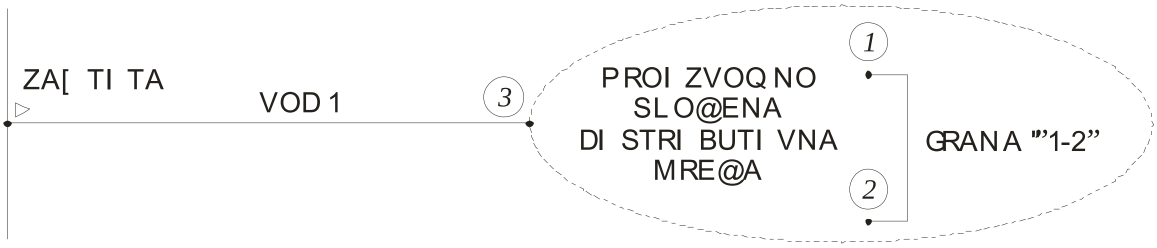

Figure 2*: Distribution network from the point of view of protection*

The general model of the distributive network, from the point of view of the protection settings has been showed on figure 2. Corresponded equivalents of those networks have been showed on figure 3 and figure 4. The detailed procedure for calculating those equivalents are presented in references [2] and [3].
It's been already pointed that detached element on figure 1 could be represented with parameters A, B, C, D, which are complex in general. The same observation values for the branch 1 – 2, which has been showed at figure 2. Those detached elements both in the transmission and distribution network, could be replaced by Π, T, Γ or inverse Γ equivalent, dependable of current situation and problem. This statement values also for the branch where the protection element has been installed. The faults are asymmetric in general, and because of that fact, the equivalents have to be calculated for the direct, inverse as well as zero sequence of the system.

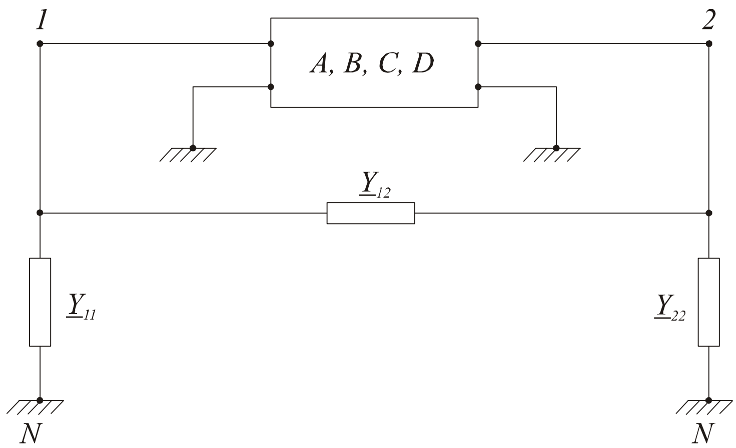

Figure 3*: The equivalent of the network showed at figure 1*

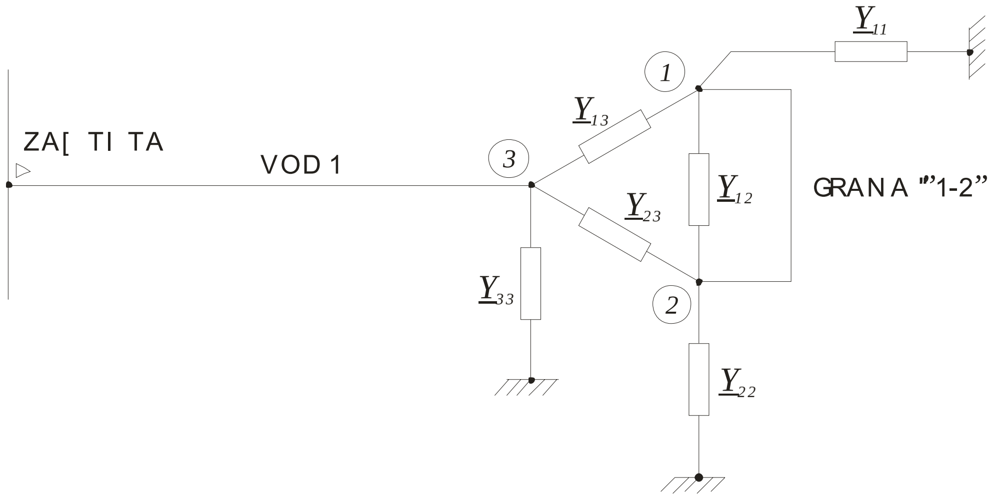

Figure 4: *Equivalent of the network showed at figure 2*

1.2 The models of the fault place

The asymmetries are in general divided on short circuits and serial asymmetries (breaks and interruptions). The very often case combination of those two faults. The differences are also in that way whether the faults are direct (metal faults Z=0) or indirect (across impedances, arc …). In general, if the fault are across the arc, arc is modeling with constant impedance (for the analyze of protection, quite enough approximation). The developed software solution gives the possibility for selection of one of those two asymmetries.
As it's mentioned before, the fault has been initiated at detached element, without observation on the selected network and equivalent model.
The general case for the short circuit model has been showed on figure 5. The general case for serial and complex faults are showed at figure 6. The model for complex faults in general contains model on figure 5.

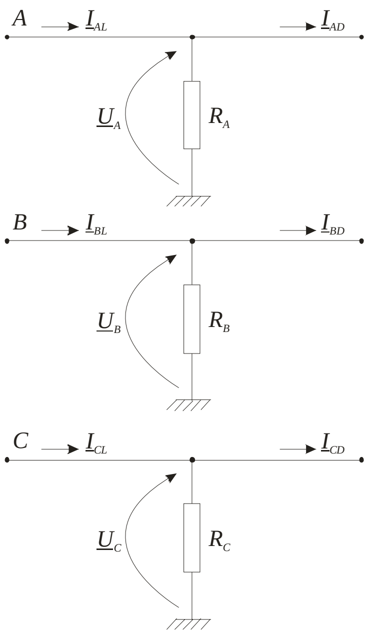

Figure 5: *The general short circuit model*

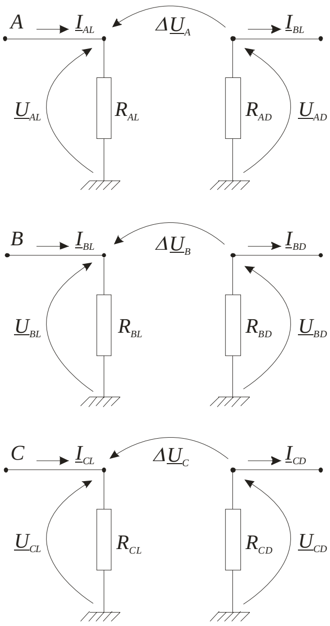

Figure 6: *The general model of the fault for complex asymmetries*

Starting from models of asymmetries shown at figures 5 and 6, it is possible to initiate all kind of faults which are possible in the electric power system. It is possible to specify all the parameters of faults which presents iterative impedances on the fault place(from both sides of fault). As the result we are seeking for currents and voltages at the fault place. The results are in the symmetrical sequences, but it is not hard to calculate real values of these parameters.
Mathematical models of all asymmetries are built from the basic equations of the short circuits and breaks(Reference [1]). Converting these equations into symmetric components, together with equations written on a base of Kirchoff's rules, we get the full system of equations which is able to be solved.

3. PROGRAM SOLUTIONS

Program for fault evaluation is designed for the part of calculations which lead to the solutions needed for relay protection settings. It consists of two parts. One is based on the equivalent in 2 nodes and it is adapted for the transmission networks, where the protection relays are installed in the beginning of every line, and each element has its own protection. The other one calculates the equivalent in three nodes and it is based on calculations which are in simplified form represented in last chapter. In this paper the focus will be given on the second solution. The goal of the program is to evaluate the characteristic values like currents and voltages in all three phases as well as zero sequences of currents and voltages on the place where the protection relay is installed and also these parameters in the steady state normal condition.
Block diagram of the complete software solution is given on figure 7.
The Software consists of three main modules: visual interface module, FORTRAN DLL modules, and Technical Database.
In the near past, distribution companies has begun with building of complete technical databases. The aim of that project is to collect all necessary data about the network at one place and make easy current maintaince and future research in that field. For these calculation it's necessary to know all parameters of the elements in the mid voltage network as well as some parameters in the high voltage as well as in the consume area. For this program, Database must be consisted of the next elements:

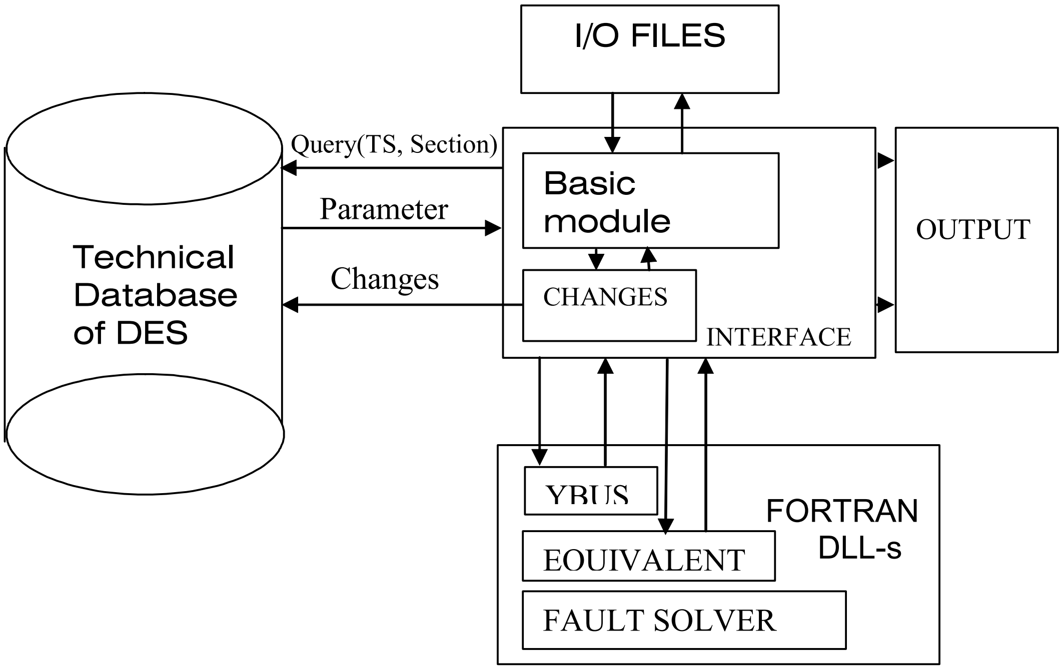

***Figure 7** : Block diagram of the software solution*

Lines	Transformers	Sections	Consume (10/0.4)
Number of node 1	Number of HV node	Number of section	Active load
Number of node 2	Number of LV node	Name of section	Reactive load
Name of node 1	Name of HV node		Number of node
Name of node 2	Name of LV node		Nominal voltage
Length	N(kV/kV)		Coordinates of node
R(Ohm/km)	Sn(MVA)		Name of the node
X(Ohm/km)	Pcu(kW)		
Supply transformer(from list)	Uk(%)		
Section(from list)	Grounding impedance		
Coordinates of node 1	Coordinates		
Coordinates of node 2	Supply transformer		

***Table 1-** Attributes of the database tables*

All the necessary data are transferring from the database on a base of query which is performed against database. The query attributes are supply transformer and one of its sections. As the result, the database returns parameters of the elements belonging that transformer and corresponding section.
The next step is to get Ybus matrix from the collected parameters. For that step, it's been used a standard Ybus building method developed through the FORTRAN routine shared as a dynamically linked library. Ybus matrix is built for direct, inverse and zero sequence. Ybus parameters and the summary number of nodes are shown on the screen.
Ybus as well as Ybus0 are now reducing on three nodes as it's shown in chapter 2.1. The equivalent parameters of symmetric sequences are developed through the FORTRAN routine EQUIVALENT which is also shared as DLL. As the output, routine returns Z parameters of the equivalent network, got from Yekv matrix(Figure 7).
The final step in the calculation procedure is to write the equations based on the Kirchoff's rule, together with additional equations based on specific fault condition. On the other words, it's needed to solve the equation system with, in the case of short circuits, 34 variables. For that problem it's been used a Sparsity method for solving a sparse linear systems. Beside the short circuits, in this paper it's

been considered serial and mixed faults also. Mixed faults demands two additional equations, but it is not a big problem for matrix to be extended. As the result program returns complex values of currents, voltages on the place where the relay is installed, and also currents form both side of the fault place. Together with these values, program returns a zero sequences of currents and voltages measured by relay. This routine is realized through FORTRAN program FAULTSOLVER, shared as DLL also.
The communication between modules and users is performed through the windows orientated interface. Some characteristic windows of the interface will be given in next chapter. The interface is realized in VISUAL BASIC as the simplest solution, but it is in the phase of development the interface written in VISUAL C++.
Through the interface, the database could be created and changed also. Communication with database is realized through an ODBC connection. For example, the screen for creating and updating line model is given on Figure 8.

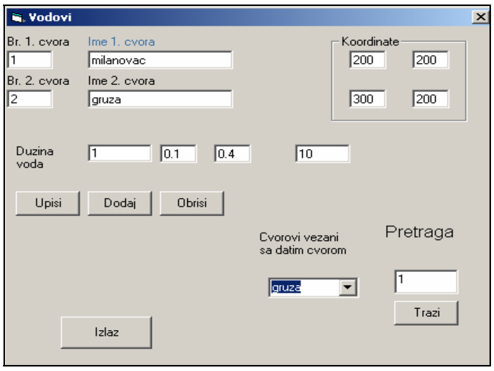

Figure 8: *Changing line parameters*

The elements of the network are graphically displayed on the screen and any separate element of the system could be accessed through graphic interface, with updating its parameters.
The communication with calculations made in FORTRAN routines is realized by calling dynamically linked libraries(DLLs).
There is also ability to save some specific cases and restore them later by saving parameter information in separate files with .flt extension. This allows one to make changes to the system and search for better solution from the point of view of faults, without direct charging of database.

4. EXAMPLE

Through the application of the developed algorithms or in the other words developed mathematical models of the network, it's been tested a 3-phase short circuit in the TEST 10 kV network with 11 nodes. The network is captured from I/O file created before. The main window is showed on the figure 9.

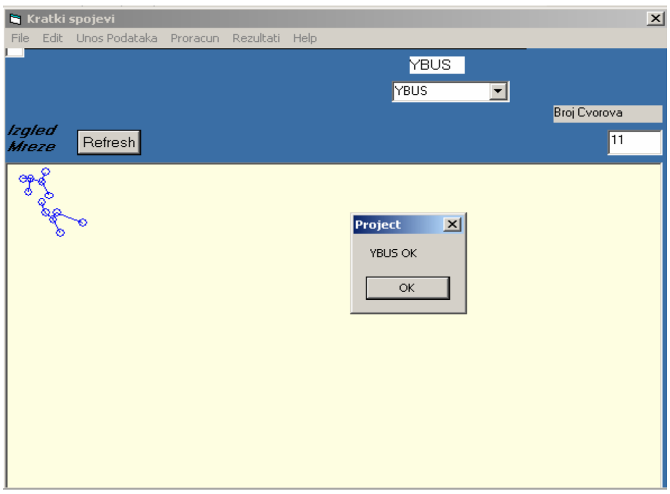

Figure 9: *The main window of the application*

There is also the graphical view of the network on the screen. Then It's been performed a network check for the validity of connections. After that, the network calculations could be done. The first is making Ybus matrix. After successful calculation, the message YBUS OK is displayed on the screen(Figure 10). The next calculation is making equivalent of the network. The equivalent routine demands choosing the three points. The firs two are the connection nodes of the element with fault, and the third one is node where relay has been installed. In this example these nodes are 2, 3 and 11 respectly.

When the equivalent is calculated, the next goal is to solve the fault. The window for choosing the parameters of the fault is displayed on Figure 10.

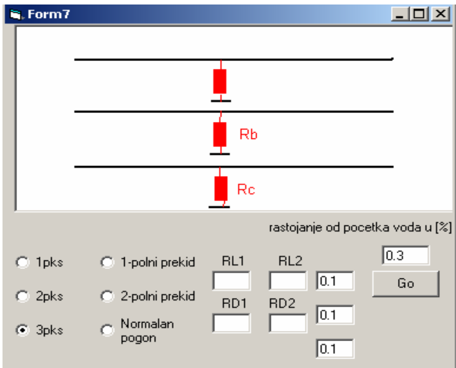

Figure 10 *: Fault parameter window*

In this example its been chosen a 3- phase short circuit with impedances of fault of 0.1 Ohm for each phase. There is also ability to chose any of the short circuit faults as well as any of the serial faults together with the all of their parameters(Figure 10.).

After all these calculations, the results can be represented.

The results are also graphically displayed like it is shown at Figure 11.

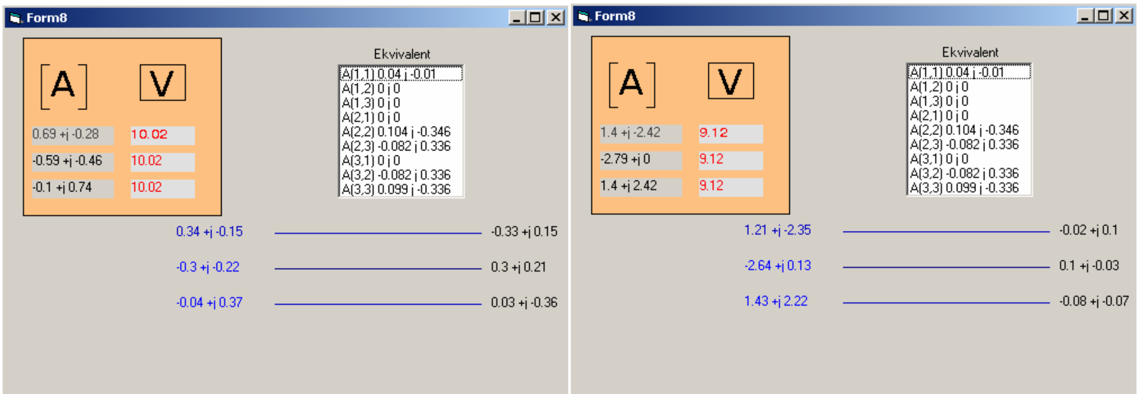

Figure 11 *: The results of the 3-phase short circuit on the TEST network*

The first window shows the results in the steady state normal conditions, and the second in the 3-phase short circuit. As the results, it's been showed the currents in each of 3 phases, at the fault place both from the left and the right side of the fault, as well as the currents measured by relay at the beginning of the section. The voltages of each phases has also been displayed.

The calculated values in the steady state could be very useful for overcurrent relay settings. The both results must be taken into consideration for short circuit protection settings because all of these values are keys on time characteristics of the relay.

CONCLUSION

The results shown in previous chapters give the correct picture of the fault conditions. The formed mathematical models and modularity of the program enables each part of the software to be incorporated in some other program solutions. Testing of this program in some concrete cases should lead to affirmation of the developed algorithm and correction of the eventually errors, and to improvement of its usage value.

REFERENCES

1. M. Djuric "Tehnika zastite u elektroenergetici", 1998, ETF Beograd.
2. M. Djuric "Reseni problemi iz relejne zastite teorija kratkih spojeva I prekida",1998, ETF Beograd.
3. V. Strezoski, D.S.Popovic "Proracuni stacionarnih rezima EESa" , 1994. FTN Novi Sad.
4. G. Đukić, M. Đurić, M. Alimpijević, S. Erac, Proračun struje tropolnog kratkog spoja pomoću ekvivalenta mreže baziranog na matrici admitansi čvorova, JUKO CIRED, R-4.10, Vrnjačka Banja, 15-18. oktobar, 2002.