METHODS OF IMPROVING THE FUNCTIONING PERFORMANCES OF LOW TENSION NETWORKS

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SUMMARY

In this article it's presented the possibility to insert in electric distribution networks a rated voltage higher than 400 V.
The estabilishment of the rated voltage is made on the basis of optimizing criterions.Structural modifications are also pointed at electric lines to low voltage,made because of the usage of new stage of rated voltage.
The paper aims to present a method of power supply of single-phase and three-phase consumers,with energy of 230V and 400V respectively ,from an electrical network whose rated voltage is 690V.
The efficiency of the method results from the presented case study ,where two cases are analyzed,for a low voltage distribution network,by applying the technical-economic criteria of minimum actualized total costs.

Key words: rated voltage,distribution networks,consumers,optimizing.

1. REGULATIONS AS REGARDS THE STANDARDIZATION OF THE VOLTAGE FOR ELECTRIC SYSTEM TO LOW VOLTACE

The International Electrotechnology Commission (ICE) decides (year 1983,Publication no. 38) to standard the series of rated voltage, both low and mean voltage, taking into account the values of existing voltage and of the others will be developed. In our country these prescriptions are written in STAS 930/1989, a document through that our country has accepted the IEC publication.

Thus, IEC advises to use 230/400 V as reference voltage with percentage limits ±10 % than the three stages of voltage 220/380 V, 230/400 V and 240/415 V,used for electric networks to low voltage analyzing rated voltage written in table no1. 1it's seen the possibility of usage of voltage stage as 400/690 V for electric distribution networks with three conductors, in both regulations.

TABLE 1 – RATED VOLTAGE REGULATED FOR ELECTRIC NETWORKS OF ALTWERNING CURRENT TO LOW VOLTAGE

Three-phase networks with furor three conductors		
IEC 38/1983	STAS 930/1989	
U_N, V	U_N, V	Percentage error, Δu%
-	120/208	±7%
230/400	230/489	±10%
277/480	500	±10%
400/690	400/690	±5%
1000	1000	±10%

In the main,IEC Publication no. 38/1983 decided to use the voltage as 230/400 V for electric networks to low voltage of public distribution, tu supply the house-consumers and the electric lighting or socially, commercially consumers, and the voltage as 400/690 V and 1000V named above but having Avery high absorption power.

Through STAS 930/1989 Romania accepted ICE Publication, taking necessary steps for the tangent of the rated voltage from 230/380 V to 230/400 V in electric networks to low voltage. In the same time the introduction of the stages of the rated voltage, as 400/690 V or 1000 V are remarked presenting the advantages against the rated voltage used at present:

- electroinsulating materials, the component elements and the technology of building of electric lines are not significant changed;
- the improdvement of the economical achievements through the reduction of power and active electric energy(c.p.t.) loss;
- the improvement of technical achievements in operation of electic lines the rise of transported power, the enlargement of transport distance, the guarantee of protection sensibility.

The usage of a rated voltage stage higher than 230/400V imposes to take steps for the protection against electrocution through direct touch and the protection against electrocution through indirect touch,connecting to earth.

The usage of a rated voltage stage as 690 V or 1000 V is proposed to realize to electic networks with four conductors and only making a technique-economical analysis comparing the possible energetic solutions.

2. THE ESTABLISHMENT OF RATED VOLTAGE IN ELECTIC DISTRIBUTION NETWORKS ON OPTIMIZING CRITERIONS

Following elements composes the mathematical pattern used for the establishment of the rated voltage in an electric network:

Optimizing sizes are represented by two unknowns together forming the vector of optimized sizes X= $[U, N]^t$, where:

U – the line rated voltage of the electric network, measured in V or kV;

N – the number of the same paths of winding, circuits or electric lines necessary for a consumer or certain area of consumption.

Optimizing function is made using the calculus of formula of yearly expenses, where the exploitation expenses terms C_{ex} and damages because of accidental dbreaks D, aren't taken into account, because of the similar configuration and structure of electric network :

$$\text{C.A.} = \frac{1}{T_N}(I + I_{ech}) + C_p \qquad (1)$$

Investment expenses I, are expressed in proportion with rated voltage of electric network and paths of winding number, thus:

$$I=N\cdot(A+B\cdot U)\cdot l \qquad (2)$$

where: A – constant representing designing expenses, the obtantion of approval and agreements and so on, irrespective of line voltage in Euro/km;
B - constant statistical determined, representing specify expenses for build an electric line, in proportion with its rated voltage, in Euro/km;
l – the lenglet of electic network, in km; thus the value of specific expenses of investissment on the length unity of the line is obtained.
Optimizing function represented by the yearly expenses will be:

$$F(N,U)=N(A+B\cdot U)+C\frac{S_M}{N\cdot U} \qquad (3)$$

Where, $C=\sqrt{3}\cdot\rho\cdot j_{rc}\cdot c_w\cdot\tau\cdot T_n$ can be considered a constant for power sizes of a consumer characterized by S_M and T_M (respectively τ **)**
The restrictions of optimizing sizes are following kinds:
- technical restrictions imposed by the realizing of electric network:

$$1\le N\le N_{\max} \qquad (4)$$

where: $N_{\max}$ – maximum number of paths of winding, represented by number of conductors (mains) on the pleas for the same electrical line or number of electric lines (circuits) equipped of a single conductor (main) on a please, supplying a consumer or a consumption area;
- technical restrictions imposed by the rated voltage level, admitted by regulations a standards;

$$U_{n\min}\le U\le U_{nmx} \qquad (5)$$

where: $U_{n\min}, U_{nmx}$ – the minimum and maximum value of the line rated voltage in distribution networks to low voltage, corresponding to the posed regulations;
- technical restrictions of power quality imposing the obtantion of perceptual voltage drops in admitting limits, corresponding to kind of network and stage of voltage:

$$\Delta u\% \le \Delta u_{adm}\% \qquad (6)$$

where: $\Delta u\%$ – the perceptual voltage drops realized for the maximum charge transported;
$\Delta u_{adm}\%$ -the maximum value admitted to perceptual voltage loss.

Optimal value of operation voltage to electric network is obtained for $\frac{\partial F(N,U)}{\partial U}\equiv 0$,resulting the relation of calculus generally applied, for electric network for public distribution, for N=1,2,….,$N_{\max}$:

$$U\equiv\sqrt{\frac{C}{B}\cdot\frac{S_{\max}}{N^2}} \qquad (7)$$

The value obtained measured in V or kV permits the establishment of rated voltage to electric network on length unity in proportion with maximum charge transported as voltage step standardized corresponding to the passed regulations. For chose of rated voltage it’s necessary to know the following technical considerations:
- electric lines of supply to the consumer or to the consumption area is realized for the same operation rated voltage;
- the rated voltage of operation to the electric network must be the same with the using voltage of receivers, 230/400 V; the choose of one voltage step[higher thou this one will be explained using the technique-economical calculations to compare the solutions;
- the restriction test as regards the admitting drop $\Delta u_{adm}\%$,for every point of consumption to the electric network and the determination of maximum usage lenth in proportion of maximum charge transported. The constants A and B are determinate in proportion with specific indicator,for LEA 0.4 kV simple circuit or LEC 0.4 kV with a single cable on the same path and respectively LEA 0.4 kV double circuit or LEC 0.4 kV with two cables on the same path realizing the electric networks to low voltage.

From energetically print of view considered the maximum apparent power between 30 and 300 kVA and its using time of (1500-4500) hours/year, which corresponds , to the functioning states of the distribution electric networks.

It's to monition that the level of the rating voltage of 1000 V, which corresponds to the maximum level of low voltage, care be accepted in the present structure of distribution networks of low voltage. While demands the existence of the neutral conductor , with the achievement of the report between phase voltage and line voltage of 580/1000 V. The rating voltage of 1000 V in IEC Publication no 38/1983 , is recommended for the electric networks of low voltage with three conductors (neutral and isolated), for supplying some industrial and similar consumers with electric energy.

TABLE 2 – THE OPERATION RATING VOLTAGE FOR THE ELECTRIC NETWORKS OF LOW VOLTAGE

Calculation Terms	S kVA	$U_{calculated}$, V				$U_{adopted}$,V			
T=3000 hours/year		N=1	N=2	N=3	N=4	N=1	N=2	N=3	N=4
τ =1575 hours/year	30	304	-	-	-	400	-	-	-
j_{ec} =0,65A/mm ^{2}	50	393	-	-	-	400	-	-	-
	70	465	-	220		690(400)	400	400	-
C=80 $\frac{kVeuro}{kmkVA}$	100	556	329	220		690(400)	400	400	400
	200	786	466	310		1000(690)	690(400)	400	400
	300	962	570	380		1000	690	-	-
T=4500 hours/year	30	318	-	-		400	-	-	-
τ =2890 hours/year	50	410	-	-		400	-	-	-
j_{ec} =0,55A/mm ^{2}	70	485	287	-		690(400)	400	-	-
	100	580	343	229		690(400)	400	400	-
C=90 $\frac{kVeuro}{kmkVA}$	200	820	486	324		1000(690)	690(400)	400	400
	300	1004	595	396		1000	690	400	400

The levels of the rating voltages resulted by the application of the relation (2.9), determinates the choise of the energetical solution in comparation with the number of electric feeder lines (circuits).

The application of au technique-economical comparison criterion of the solutions, allows the choice e of the optimized solution while demand to take into consideration the investments expenses, and exploitation expenses and for electric energy losses, depending au the voltage stages possible for usage in the low voltage networks.

Observation: The values in the parenthesis , reduced with one step on the scale of the regulated rating voltages, can be adopted with the restriction checking (6).

3.SOLUTIONS FOR IMPROVING THE TECHNICAL-ECONOMIC PERFORMANCE IN LOW VOLTAGE ELECTRICAL NETWORKS

The three-phase distribution electrical networks with the rated voltage of 400V, are supplying sources with electrical energy of three-phase consumers which utilize the receivers at a voltage of 400V and of single-phase consumers which utilize the receivers at a voltage of 230V. These are made as overhead electrical lines or as cables with radial operation, which have a source node or two source nodes (the case of electrical networks with booking or looping possibilities) and one or more consumption nodes. The source nodes of the 400V distribution networks are the medium voltage transformer stations /0.4kV powered from the distribution electrical network of 6-20kV.

The current operation conditions of the 400V distribution networks are influenced both by the increased electricity consumption due to the enhancement of the electrical power installed in households and the appearance of small consumers, and also, by the structure of the electrical lines caused by the conception of execution.

Most low voltage distribution electrical lines are older than 20 years, with lengths much greater than those recommended and having sections of the conductors below the economic values. Their

functioning in the current operating load, leads both to overcoming, in many cases, the allowed voltage drop, which affects the quality of the electrical energy supplied to consumers, as well as increasing the power and electrical energy losses in the power lines, which economically affect the distribution units of the electrical energy.
To obtain the quality indicators of electrical energy and to achieve the economic operation of 400V distribution networks, the following technical solutions are used:
- creation of new injection points in the 400V distribution network;
- replacement of conductors with others that have superior sections compared to the existing ones;
- construction of new electric lines or circuits with an operating voltage of 400V.
Creating a new point of injection involves the construction of a medium voltage electric line for connecting a transformer station. Although this method conveniently solves the problems related to the operation of the low voltage distribution network, it has the following drawbacks:
- high investment costs for the works of achieving the medium voltage connection, the transformer station and the sectioning works of the 400V electric lines;
- further maintenance – exploitation costs due to the increased volume of the distribution electrical installations;
- difficult conditions for constructing new facilities due to the problems of obtaining the land occupancy agreements and the coexistence permits with other facilities.
The other applicable solutions to public distribution electric lines, are less utilized due to the lower technical and economic efficiency, they usually solve the problems of a single circuit and of the limited maximum value, for the section of aluminum conductors.
A new method that aims to improve the technical and economic performances lies in the utilization of a superior rated voltage compared to the one of 400V for the distribution electrical networks, within the limits governed by national and international standards (SR EN 15060/1998, STAS930/1989, CEI 38/1983 Publication).
Introducing a voltage superior to the one that is currently used of 400V, as a rated operating voltage of distribution electric networks, results in eliminating the inconveniences related to the construction of new installations, transformer stations, medium and low voltage electric lines. The method presents advantages related to keeping the construction elements of existing electrical networks and allows the improvement of their quality, performance, voltage level, power and electric energy losses, etc. with a minimum financial effort, lower than the current solutions. To be noted that one of the constructive elements which adversely affects the operation of low voltage networks, the maximum length used, does not need to be changed (reduced) in the case of utilizing a rated voltage superior to the one of 400V.

4.THE STRUCTURE OF A LEA WHICH OPERATES AT A RATED VOLTAGE OF 690V

The use of the 690V rated voltage in the specific structure of low voltage distribution electric lines with four conductors, is made in accordance with energetic prescriptions, technology and instruction sheets in the field, and with the standards for low voltage installations operating at the 400V rated voltage.
It is necessary to mention that regardless of the rated voltage value of the distribution electric network, the power supply voltage of electric receivers remains the one used in the present, which is 230V for single-phase receivers and 400V for three-phase receivers.
Figure 1 shows the single-phase diagram of an overhead electric line operating at a rated voltage of 690V, radial powered from the medium voltage network through a medium voltage/690V transformer station.
The connection of consumers to the 690V electric network is done through single-phase low power transformers of 400/230V, realized in the range of the 2, 4, 6, 10 kVA rated power.
Single-phase low power transformers can supply one or more single-phase consumers through electrical connections; the number of single-phase consumers connected from a transformer is limited by consumers' density and by respecting the technical conditions of the connections.
The power supply with electric energy of three-phase consumers is made by utilizing the same types of low power transformers, in a three-phase assembly.

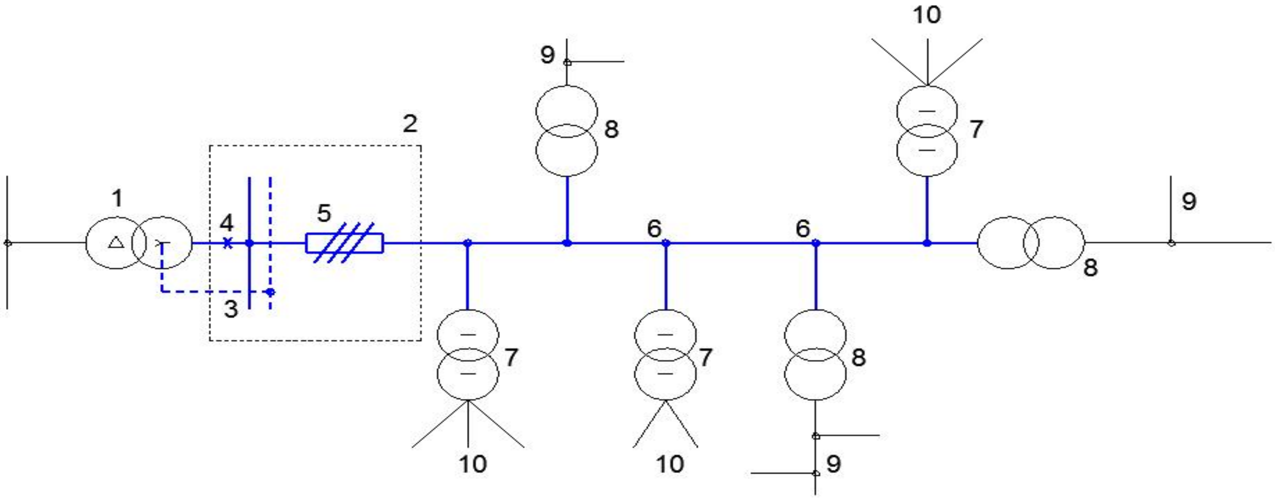

FIG. 1. SINGLE-PHASE DIAGRAM OF A LEA WITH A RATED VOLTAGE OF 690V
1. Medium voltage power transformer /690V; 2. Distribution box; 3. Collecting bars; 4. Automatic breaker; 5. Safety fuses; 6. 690V overhead electric lines; 7. 400/230V single-phase low power transformer; 8. 690/400V single-phase low power transformer in a three-phase assembly; 9. 400V overhead electric line; 10. Single-phase connections

5. CASE STUDY

The technical-economic comparative analysis of the power supply methods of consumers by using minimum actualized total costs criteria – CTA for the following methods (versions):
- version A: the classic solution – injection from the 20kV electric network through an overhead transformer station (PTA) in the 400V distribution network and the consumption distribution on two transformer stations;
- version B: the proposed method – passing the low voltage electrical distribution network at a rated voltage of 690V and supplying the consumers through low power single-phase transformers 400/230V.

The calculating relation for CTA, taking into consideration that the investment works are executed in less than a year, is:

$$CTA = \left(I_d + I_{ech}\right)\left(1+a\right)^{-1} + \sum_{i=2}^{t}\left(C_{ex.m} + C_p\right)\left(1+a\right)^{-i} \qquad (8)$$

where, I_d – direct investments for the completion of the electrical installations;
t – normal life span of equipment, 30 years (Table 3).

TABLE 3 - INVESTMENTS BY TYPE OF ELECTRICAL INSTALLATIONS

Direct investments by type of electrical installations	Version A (euro)	Version B (euro)
LEA 20kV simple circuit	132488	-
PTA – 20/0.4kV, 160kVA	65459	-
PTA – 20/0,4kV – change in the ratio of transformation	-	12500
LEA 0.4kV – sectioning regulatory connections	68535	-
LEA 0.69kV – low power transformer installation, earth electrode, regulatory connections	-	81100
Low power single-phase transformer TMMP 400/230V	-	95200
Total	266482	188800

I_{ech} – equivalence investments are determined by the following relation:

$$I_{ech} = k_r \Delta p \cdot c_p \qquad (9)$$

where, c_p=1250 €/kW=5312.5 lei/kW (it was considered an exchange rate of 1€ = 4.25lei).

ΔP – active power losses, detailed in table 4;
k_r – reservation coefficient of power in the energetic system, k_r=1.2.

TABEL 4 - THE ACTIVE ELECTRIC ENERGY LOSSES

Electric equipment	Version A		Version B	
	ΔP, kW	ΔW, kWh	ΔP, kW	ΔW, kWh
Existing PTA – 20/0,4kV	1.138	8834.3	-	-
Designed PTA – 20/0,4kV	1.04	4943.5	-	-
Designed LEA – 20kV	0.005	7.6	-	-
Supplied from the existing PTA, LEA – 0.4kV	1.072	1688.9	-	-
Supplied from the designed PTA, LEA – 0.4kV	1.356	2135.7	-	-
PTA – 20/0.69kV	-	-	1.76	9816.2
LEA – 0.69kV	-	-	1.32	2085.1
*TMMP – 400/230V connected in LEA 0.69kV	-	-	3.01	11833
Total	4.61	17610	6.09	23734.3

*Idle running and short circuit loss values are those resulted in their designed phase.

The following investment values of equivalence are obtained:

$I_{ech_A} \cong 29389 lei$; $I_{ech\,e} \cong 38824 lei$

C_{exm} – maintenance – exploitation costs, determined as percentage values from the direct investment values, as follows: PTA – 20/0.69(0.4)kV – 6%;
LEA (0.4-20)kV – 5.5%;
TMMP – 400/230V – 6%.

C_p – costs due to electricity losses, calculated considering the price (without VAT) of electrical energy for residential subscribers, c_w=0,433lei/kWh and the active electric energy losses in Table 4.

The maintenance – exploitation costs and also the costs due to the loss of electric energy are as shown in table 4.

TABLE 5 - TOTAL COSTS

Costs type	Version A (lei)	Version B (lei)
Maintenance – exploitation	14984	10923
Costs due to the active electrical energy losses	7626	10277
Total costs (lei)	22610	21200

The total costs actualized for the lifespan of the equipments t=30 years are shown in table 5, where it can be seen the normalized timescale for the recovery of investments T_n=10 years and also the recovery rate a=0.1.

TABLE 6 - MINIMUM ACTUALIZED TOTAL COSTS CRITERIA – CTA

Version	Year	Investment costs I_d+I_{ech} (lei)	Maintenance – exploitation costs $C_{ex.m}+C_p$ (lei)	Updated factor	CTA (lei)
A	1	295871	-	0,909	268947
	2-30	-	22610	8.513	192479
	Total		-	-	461426
B	1	227624	-	0.909	206910
	2-30		21200	8.513	180476
	Total	-			387386

It can be noticed that version B – method to improve the technical conditions of supplying consumers with electricity using the rated voltage of 690V shows minimum CTA.
The total costs for version B show a reduced value of up to 16.04% in comparison with the costs for version A. Version B also has the advantage of a reduced investment effort of 29.15% at the beginning of the work, which implies a shorter time scale for the recovery of investment costs, when compared to the traditional version.

6.CONCLUSIONS

The insertion of a new step at the rated voltage, more precisely 690V, it is supposed to be implemented not only within the electrical network of public distribution of low voltage, but also for supplying with electrical energy those consumers using receivers with operating voltage of up to 690, 400 and 230V.
The execution of works such as ICTAEE (improving the conditions of supplying electrical energy) within the low voltage electrical networks shows the following advantages:
- it maintains the configuration and structure of the 20kV electrical network and also of the low voltage electrical network, which it will function fully or partially at a voltage of 690V;
- the components, the technology and the materials used within the 690V electrical network are those already known, the only elements which come as new in their structure being the single-phase low voltage transformers of 400/230V.

Technically speaking, the suggested method leads to the improvement of performances within the operation of low voltage electrical network by:
- reduction of the absolute and partial voltage loss at approximately 58% of the voltage loss values obtained when the network operates at 400V;
- increased length of low voltage electrical lines of up to three times in comparison with the optimum realization length – normal functioning of a voltage line having the rated voltage of 400V;
- increased value for the conveyed voltage for the same economic current density of up to 1.73 times;
- reduction of power losses and active electrical energy within electric lines of approximately 63% compared to similar losses at a 400V voltage; reduction of power losses and electrical energy due to the use of low power transformers, in relation to their number and rated power;
- increased sensitivity protection by using safety fuses due to the growth in value of single-phase short circuit of up to 1.73 times, but also for the possibility of using safety fuses with lower nominal voltage values, equal to the load current at nominal network voltage of 690V.

LIST OF REFERENCES

1. Bercovici M., Arie A, Poeata Al,1978, ″ Electric networks – Electric calculation ″ Tehnical Publishing House,Bucuresti
2. Iacobescu Gh, Iordanescu I, Tudose M,1979 , ″ Electric networks and Systems ″ Tehnical Publishing House, Bucuresti,
3. Popescu S, Stan C, Sotri S, 2003, ″ Optimizatins of the electric networks ″Macarie Publishing House, Targoviste