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ENERGY EFFICIENCY IMPROVEMENT IN A WATER PUMP STATION WITH STATIC CONVERTER OPERATION

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Abstract: The paper presents the symbolical-numerical simulation of the operation of a uncontrolled static rectifier-inverter voltage converter. One presents a circuit mathematic model, made in symbolic form based on the state equations method in combination with the two graphs method.

The circuit equations solving is performed in a numerical manner. Therefore the analysis accuracy is very good and the danger of stability loosing during the calculation process is considerably reduced.

Key words: energy, circuit, pomps, centralized system

1. INTRODUCTION

The electric circuits analysis are required during various stages: the designing stage, the test stage (to perform some settings), the exploiting stage (to anticipate the behaviour during operation conditions changes e.g. load or network supply characteristics) or the service activity (to explain some abnormal behaviours and to identify some defects that might occur) [1], [8], [9].

In some situations only a restricted set of parameters (considered as analysis results) present interest and the conditions imposed to accuracy are less restrictive. Under these circumstances the analysis algorithm is significantly simplified. On the contrary, the analysis required during the designing stage is much more complex.

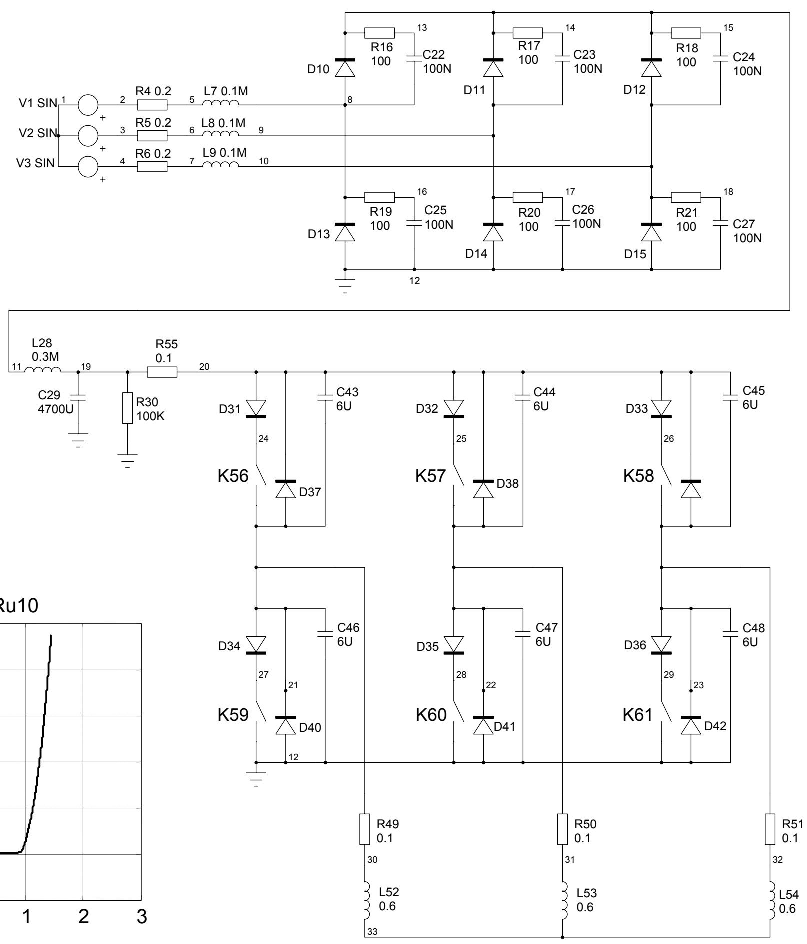
2. ANALYSIS METHOD

One presents a circuit mathematic model, made in symbolic form based on the state equations method in combination with the two graphs method [2]. The use of symbolic calculus techniques during the circuit equations determination is significantly reducing the rounding errors that inherently accompany the numerical calculation and also highly restricts the danger of stability loosing during the calculation process. Moreover, it results in a significant reduce of the analysis time because many operations

are done only one time, in a symbolic modality and are not repeated at each step time or at each iteration. The convergence is definitely supplied for a wider class of problems as compared to the pure numerical algorithms, with a much lower calculation effort. The circuit equations solving is performed in a numerical manner.
The analysis accuracy is very good and the danger of stability loosing during the calculation process is considerably reduced [3], [4].
The program used for this analysis was desingned so as to meet the requirements of research-designing activities. It does not represent an alternative to the existing commercial programes but includes many „patches”, eliminating some of their outdraws. The aim of this paper is to present only the results yielded by this program [2],[5]-anddoes not present it in detail.

3. SIMULATION RESULTS

1. The voltage inverter is supplied by the low voltage three-phase power utility through a uncontrolled rectifier
The diodes are simulated by means of voltage-controlled nonlinear resistors. Figure 2. depicts their characteristic. The inverter switching transistors (IGBT) are simulated through parametric resistors (K6-K61). The inductive load simulated the asynchronous motor windings



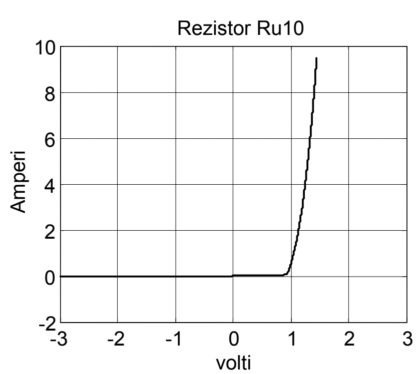


Fig. 2

Fig. 1

The use of MOS transistors results in a series of remarkable advantages:

- the operation of modular ultrasound frequencied is causing no noise;
- the control required power is significantly lower than that used when bipolar transistors are used, allowing the galvanic separation between the control and the force side by means of optocouplers;
- MOS transistors can operate without protection over the voltage increasing slope, so as the force schematic is simplified;
- modern MOS transistors include the rapide recovering diode, therefore the diodes D37-D41 from figure 1 are removed;
- the high frequency modulation of voltage pulses strongly reduces the harmonic content of motor supplying voltage with good effects overt the reducing of magnetization losses.

The state variables vector has 16 components, namely the capacitors voltages and the currents through the essential inductivities.

$$\boldsymbol{x}=[u_{22}, u_{23}, \ldots u_{24}, u_{29}, u_{43}, u_{44}, u_{45}, u_{46}, i_8, i_9, i_{28}, i_{53}, i_{54}]^t \quad (1)$$

The output variables vector has 38 components, namely the voltages of branches resistors and the currents through the chords resistors from the circuit associated graph. The topological structure, automatically builded by program, is depicted by fig. 3.

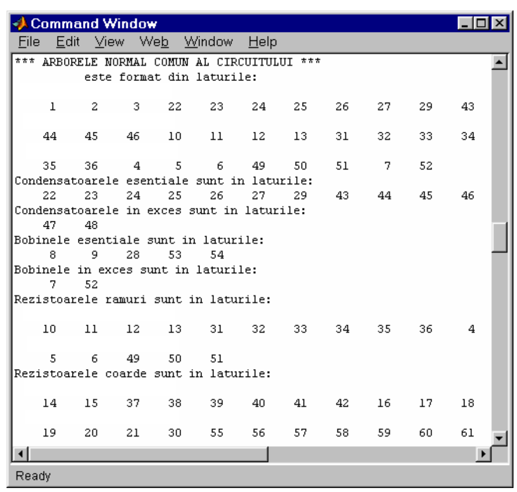


Fig. 3

The symbolic state-output equations are as follows:
- the state equations:

$$
\begin{cases}
C22*Du22 = i16 \\
C23*Du23 = i17 \\
C24*Du24 = i18 \\
C25*Du25 = i19 \\
C26*Du26 = i20 \\
C27*Du27 = i21 \\
C29*Du29 = i28 - i30 - i55 \\
(C43+C47+C48)*Du43 - C47*Du44 - C48*Du45 + \\
+(C47+C48)*Du46 = i53 + i54 + i61 - i55 - i41 - i42 - \\
-i37 + i56 + i60 \\
-C47*Du43 + (C44+C47)*Du44 - C47*Du46 = \\
= -i53 - i38 + i41 + i57 - i60 \\
-C48*Du43 + (C45+C48)*Du45 - C48*Du46 = \\
= -i54 - i61 - i39 + i42 + i58 \\
(C47+C48)*Du43 - C47*Du44 - C48*Du45 + \\
+(C46+C47+C48)*Du46 = i61 - i55 - i40 - i41 - \\
-i42 + i59 + i60 \\
(L8+L7)*Di8 + L7*Di9 = u4 - u11 + u10 - u5 - \\
-Esin1 + Esin2 \\
L7*Di8 + (L9+L7)*Di9 = u4 - u12 - u6 + u10 - \\
-Esin1 + Esin3 \\
L28*Di28 = -u29 - u13 - u10 \\
(L53+L52)*Di53 + L52*Di54 = -u43 + u44 - u50 + u49 \\
L52*Di53 + (L54+L52)*Di54 = -u43 + u45 + u49 - u51
\end{cases}
$$

- the output equations:

$$
\begin{cases}
i15+i14-i20-i21-i16+Gd10*u10+i8+i9-i28+J0R10=0 \\
-i14+i20-i17+Gd11*u11-i8+J0R11=0 \\
-i15+i21-i18+Gd12*u12-i9+J0R12=0 \\
i15+i14-i20-i21-i19+Gd13*u13-i28+J0R13=0 \\
-i56+Gd31*u31+J0R31=0 \\
-i57+Gd32*u32+J0R32=0 \\
-i58+Gd33*u33+J0R33=0 \\
-i59+Gd34*u34+J0R34=0 \\
-i60+Gd35*u35+J0R35=0 \\
Gd36*u36-i61+J0R36=0 \\
G4*u4+i8+i9=0 \\
G5*u5-i8=0 \\
G6*u6-i9=0 \\
G49*u49+i53+i54=0 \\
G50*u50-i53=0 \\
G51*u51-i54=0 \\
-u13+u11-u10+Rd14*i14+E0R14=0 \\
-u13+u12-u10+Rd15*i15+E0R15=0 \\
Rd37*i37-u43+E0R37=0 \\
Rd38*i38-u44+E0R38=0 \\
Rd39*i39-u45+E0R39=0 \\
Rd40*i40-u46+E0R40=0 \\
Rd41*i41-u43+u44-u46+E0R41=0 \\
Rd42*i42-u43+u45-u46+E0R42=0 \\
u10+R16*i16+u22=0 \\
u11+R17*i17+u23=0 \\
R18*i18+u12+u24=0 \\
u13+R19*i19+u25=0 \\
u13-u11+u10+R20*i20+u26=0 \\
u13-u12+u10+R21*i21+u27=0 \\
R30*i30-u29=0 \\
R55*i55-u29-u43-u46=0 \\
u31+RK56*i56+u43=0 \\
u32+RK57*i57+u44=0 \\
u33+RK58*i58+u45=0 \\
u34+RK59*i59+u46=0 \\
u35+RK60*i60+u43-u44+u46=0 \\
u36+RK61*i61+u43-u45+u46=0
\end{cases}
$$

In the figures 4–9 we present a part of the results, under graphical representation, obtained after the solving of the above equations for the fundamental frequency (50 Hz).

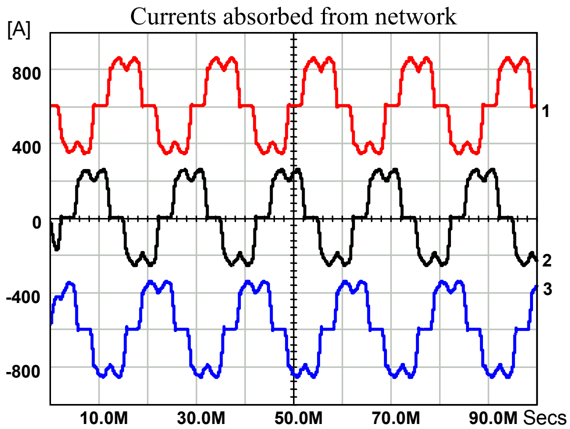


Fig. 4

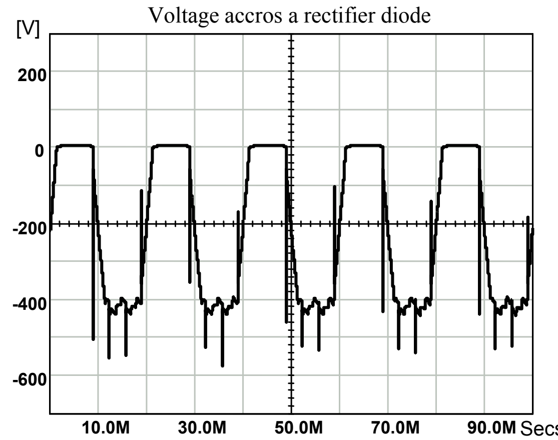


Fig. 5

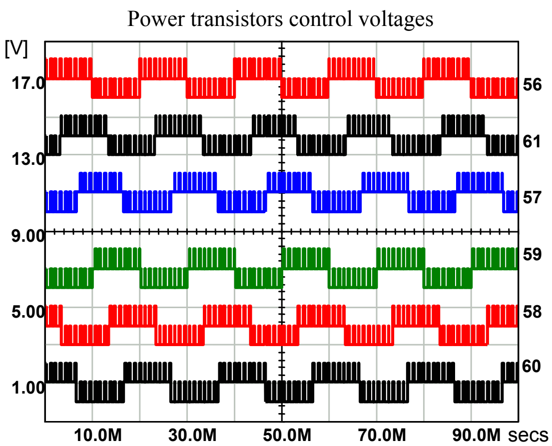


Fig. 6

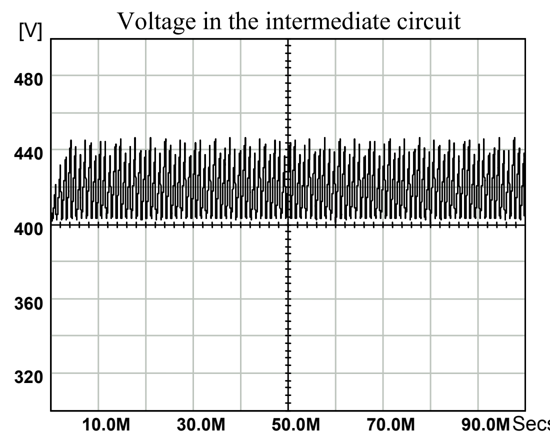


Fig. 7

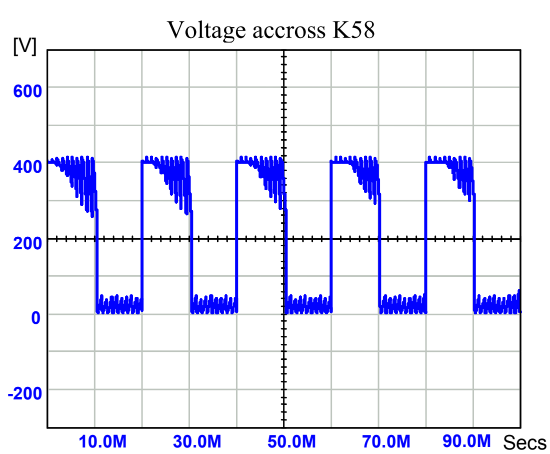


Fig. 8

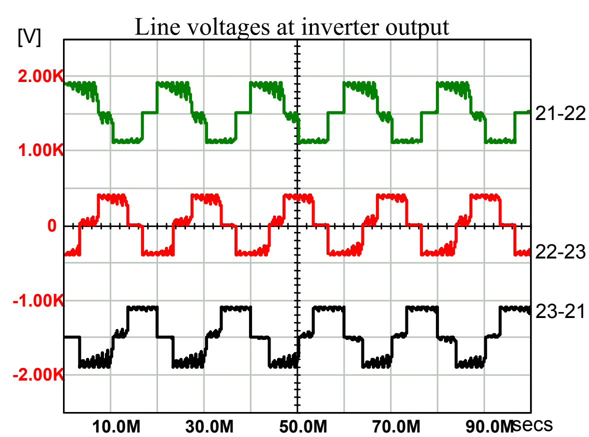


Fig. 9

4. CONCLUSIONS

The above results were obtained after repeated simulations. Even from the designing stage they made possible the proper determination of the schematic components parameters. Based on them a prototype was conceived and presently it operates [5]. No modifications were required since the beginning of its operation. The results of test desk tests reproduced, with unsignificant deviations, the simulation results. The small deviations can be explained as consequences of some approximations made during the mathematical model deducing and of the dispersion from the components parameters. The present adopted solution resulted in a competitive finite product from both points of view: technical and costs.

The presented methods and simulations rely on the technical implementations from the domain of driving pumps from water-pumping stations. Today in these stations the pumps operate at constant speed, the water pressure being controlled through their start/stop, depending on consumption. The four pumps are provided with 160 kV motors operating at 980 rot/min. The electric energy consumption is most of the time irrational, because the medium pressure is in excess and the consumers can notice a high pressure variation. Moreover, the pressure shocks cause rapid pipes degradations [6], [7].

The realization of a centralized system used to trigger and control the operation of installations from the pumping stations will allow the optimum operation of the motors driving system. At the same time it will increase the equipment and installations operation safeness, resulting in a more efficient energy utilization and an optimum handling of water.

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