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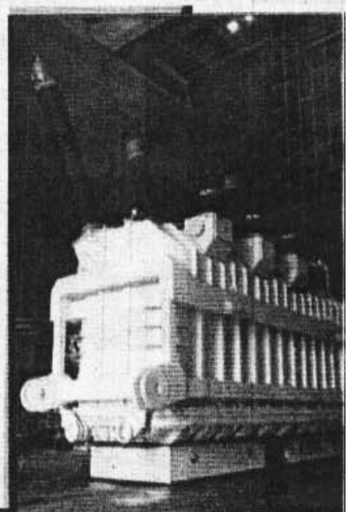

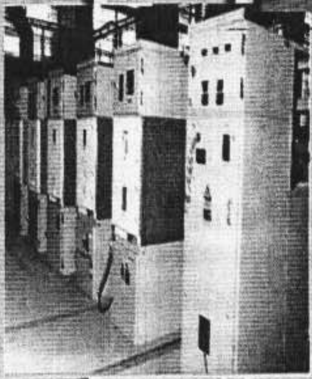

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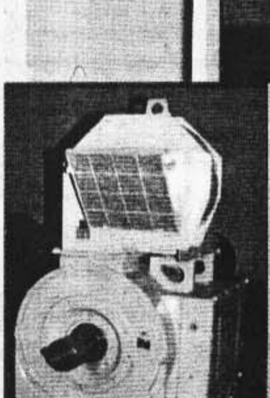

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ABOUT MODELLING OF OVERVOLTAGES IN POWER SYSTEMS AT THE TRANSIENTS DUE TO SWITCHING OPERATIONS OF MULTIPLE CAPACITOR BANKS

PETRE TUSALIU, DAN GEORGESCU, DANIEL MATEI,
RADU CHELARU, VIRGINIA IVANOV, ALIN DOLAN
UNIVERSITY OF CRAIOVA

ABSTRACT

The study presents the main disturbances, generated by the transitory phenomena at the commutation of simple and multiple capacitor banks. The same are presented electromagnetic stresses modeling features at the commutation of capacitor banks as part of the National Electrical Energetic System. Successfully used for the compensation of wattles-inductive energy, capacitor banks are characterized during connecting and re-energize of electric arc by the powerful current shocks, which produces dynamic, thermal stresses and electrical wear extremely pernicious for the commutation equipment for the banks themselves and for electrical network, thus possible serious disturbances in the Power Systems may occur. This stress evaluation is based on adequate numerical programs concerning certain equipment and capacitor banks as part of the Power Systems.

The final part of this study contains proposals and recommendations for construction, function, operation of the assembly capacitor banks-circuit breaker-network, to limit the level of stress and to rise the security in function.

1. INTRODUCTION

During the recent years there have been intensive discussion concerning the capacitance switching, particularly line - charging current switching 1-3. These works will provide general information on the physical phenomena and stresses as well as to make recommendations whether and how the standards for circuit - breakers should be revised [2,3]. A large majority of the users wants circuit-breakers which will not restrict in their networks. Exceptions are limited the bellow 245 kV for which the consequences of a restrict are less dangerous because the ratio of the permissible over voltage to the rated voltage is greater than for higher rated voltage levels. However, it remains how a circuit - breaker shall be defined as restrict - free [1-3]. The increasing use of electronic and digital technologies in power systems and the wider diffusion of sensitive utilization connected to them make the problem of Power System Electromagnetic Compatibility (PS-EMC) of great interest. There is potentially a great number of possible sources of disturbance in power systems. The paper presented refer to transients due to switching operations and faults.

2. DISCONNECTION OF THE CAPACITOR BANKS

The phenomena which appear at the capacitor banks disconnection are dependent of the breaker's specific features, the disconnected bank size and of the feeding network parameters. So, in this process, two elements are very important and these are: the growing speed of the dielectric rigidity of the space between the breaker's contacts (Ud = f(t)) and the growing speed respectively the oscillate recovering voltage amplitude (Ur = f(t)) [2, 3]. The growing speed of the dielectric rigidity dependent from others as: the breaker's contact specific features; the contacts moving speed; environment and possibilities of breaking used; the disconnected bank size, presents generally dependencies of breaker's parameters. The oscillate recovering voltage presents dependencies of the feeding voltage value induction and feeding network capacity. For the three phase circuits can be thought that the four possible cases of ties on the earth of the neutral points of these two circuits: the source and the neutral point of the feeding network and of the capacitor bank are tied on the earth, each phase can be considered in single phase circuit separate, which is not influenced by the other phases. If the neutral point of the feeding network is tied on the earth on the neutral point of the capacitor bank is isolated, which cannot be influenced by the other phases. If the neutral point of the feeding network is tied on the earth on the neutral point of the capacitor bank is isolated, the oscillate recovery voltage between the poles of the some phase of the breaker depends as much of the neighbour phases as of the bank neutral point potential.

This situation makes that the overvoltage appears only because of the capacitor bank [2,3]. Also, knowing that the network inductance is in conversely proportion with the short circuit power, it can be said that so much that the short circuit current at the bank place is smaller, as big is the initial voltage falling produced by the bank current on the inductance and a longer average time to break the electric arc. It results that, for one short circuit current, moment critical value of the short circuit current, the average breaking electric arc time-out runs the maximum time which ensures the capacitor bank disconnection without electric re-lighting [2,3].

With reference to fig. 2.1. the following values for voltage and current at the switching device (CB), apply [1-3]: The voltages U, Uc to ground at the closed breaker is higher than the source voltage Uc due to resonance effects and is given by equation (1):

$$U_1 = U_c = U_0/\left(1 - \left|\omega^2/\nu^2\right|\right) \quad (1)$$

- $\omega = 2\pi f_p$ (f_p - power frequency)
- $\left|\nu^2\right| = 1/(L_s C)$.

The capacitive current i_0 flowing through the breaker is calculated by equation (2): $i_0 = U_c \omega C$ (2)

The frequency fj, the rate of rise duj/dt and the amplitude Uj of this transient are given by the inherent features of the source network:

$$f_j = \frac{1}{2\pi\sqrt{L_s C_s}}; \quad \frac{du_j}{dt} = Z_s \frac{di_c}{dt}; \; Z_s = \sqrt{L_s / C_s}$$

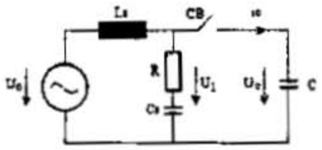

Fig. 2.1. Schematic circuit of capacitor bank switching: Ls - source inductance; R, Cs - representation of source side capacitance and dumping; Uo - peak value of source.

3. THE MULTIPLE CAPACITOR BANKS COMMUTATION

The phenomena with appear at the disconnection of the multiple capacitor bank from the network are same with the others from the simple bank disconnection if the breaker does not appear re-lighting of the electric arc [2,3]. In the case of the electric arc re-lighting, the physical process to another already working connection, and between these it is produced on discharge with a frequency dependent of the inductivity and capacity of the discharge current. The discharge current can have very high values, being dependent of the voltage difference from the step working and the step disconnected. The discharge is produced without break till the voltage difference from the two bank sizes diminishes to zero.

At the disconnection of simple capacitor banks but more especially at the disconnection of multiple capacitor banks may appear an important commutation overvoltage, which in certain occasions may become very dangerous for the apparatus-network assembly and sometime even for the environment.

Especially at multiple capacitor banks, besides the transition current shock, the switching overvoltages at disconnecting are creating important values (not to be neglected) of magnetic and electric fields, which through their amplitudes, but especially the rapid variation in time are leading directly to important stress, some-time with destructive effects with unfavourable and undesirable effects for the Power.

On the main equivalent draft base from fig. 3.1. a), of the electric equivalent parameters determined (R_ech = 0,013Ω; X_ech = 3,105Ω; Z_ech = 3,105Ω), suitable to the real elements from the circuit on base of analytic calculation [2], there made and executed on the computer many programmes, where from we select "The disconnecting voltage" which having at base the programming method it follows the electric stresses determination in transitory regime at disconnection, using the Runge - Kutta method, the results being synthetically presented in the table 1.

U [kV]	Phase difference current-voltage [degrees]	Umax [kVmax]	Ku (overvoltage factor)
12	0	24.006	2.003
	15	31.995	2.66
	30	39.693	3.3
	45	45.084	3.75
	60	-52.035	4.33
	75	-58.26	4.85
	90	-60.916	5.67

4. STRESSES AT THE MULTIPLE CAPACITOR BANKS DISCONNECTION

In the multiple capacitor banks disconnecting process results overvoltages and overcurrents which can take very big values, very often bigger then the others obtained at the capacitor banks connection, producing in this way serious stresses in the power systems. So, in the single-phase circuits at the capacitor banks disconnection without electric arc re-lighting. the oscillate recovering voltage which appears at the breaker's contacts doesn't exceed the double value of the feeding network voltage; the appearance of the overcurrents is not possible. If it appears electric arc re-lighting. The overvoltages can reach important values which can be transmitted in the feeding network under the form of some impulse waves, which amplitude is dependent by the number of re-lighting. The trickling to ground resistance and the neutral point capacity of the equivalent network transformer have a considerable influence on the capacitor banks disconnecting process. So, at small capacities and big resistance the two impedance in parallel can be comparable and the voltage stress of the trickling resistance is diminishing, the breaking of the capacitive current could be diminished a lot. At the growing of the capacity because the hard process of trickling of the charge through the big value resistance, the breaking process of the capacitive current is more complicated, on the breaking interval are adding on the initial voltage salt from the disconnected part and the industrial frequency voltage from the feeding network part. When the tie at the ground, considered on the third phase is situated down the breaker, the third pole is no more stressed and the connection which can be effectuated in the 1 - 2,3 or 2 - 1,3 succession can generate an oscillate recovering voltage of 3,46 U_{phase}, or 3 U_{phase} (when in the second stage is disconnecting pole 2). In the case of tying at the ground, on the third phase, down the breaker, the disconnection is maiden in two stages, being stressed all the poles in this way: for the 3 - 1,2 succession the maximum voltage stress of the third pole is 2,5 * U_{phase}, and for the others two, only 1,5 * U_{phase}; in the case of 1 - 2,3 succession the voltage stress at the first pole, at 90 degrees after the breaking of the current is equal with 1,73 * U_{phase}, and the maximum stress, obtained at 150 degrees after the breaking of the same current, is equal with 1,7 * U_{phase}. the other two poles being stressed with 0,37 * U_{phase} and 1,37 * U_{phase}; for the 2 - 1,3 succession the stresses are bigger at the pole which disconnects the first, so that after 90 degrees from the breaking of the current from the second phase the voltage stress of the pole is 1,73 * U_{phase} and the other two poles can reach at the value of 3,6 * U_{phase}.

There are cases where the maximum stresses of the breakers can be bigger but being given the fact that the probability of opposition of these very low, these were not mentioned. The scope of the researches is to keep abreast of relevant developments concerning electric and magnetic fields and health, to prepare state-of-art, to produce information documents and to organise panel sessions, workshops, etc. As a future activity is the implementation of models for the calculation of induced voltages and currents on cables and equipment.

5. CONCLUSIONS

The spectrum of switching arc modelling features is vast. Of course that it presents a real interest the elucidation of some aspects with general character but of details, too. So, it will be wished to know:

- what parameters of the phenomena are the most relevant for switching arc modelling;
- how, further, should the investigation go on, on traditional or new item of interest, to identify adequately the sources of disturbance;
- which are, if any, the methods for reducing the various disturbances at the sources and where these methods are technically and economically convenient when compared to alternative measures to improve the immunity of the apparatus.

From the numerous possible sources of perturbations and stresses, "transients due to switching operations and faults" have a special place.

Switching of capacitor banks is specially in case of re-strike and switching of multiple banks (the so called "back - to - back" oscillations between adjacent banks), may be source of severe disturbances. Paper examines the phenomenon for different network conditions and also the possibility to reduce the disturbance using insertion of resistors. It is tried to show, at which part of the transient is more relevant to switching arc modelling: the high frequency emissions, dumping very quickly, due to the voltage collapse across the circuit breaker contacts, or the subsequent oscillations dominated by the circuit parameters. The disconnection of the capacitor banks imposes, from the point of view of dielectric stresses (so of the perturbations introduced in the power systems) conditions very hardly at the breaker's contacts, capacitor banks and feeding network. So, the electric arc re-lighting can conduct at inadmissible stresses of isolation, which can product as much the capacitor destroy as the breakers.

It is imposed, so, that the breakers in use to function very strictly without electric arc re-lighting and without current snatches. If at the disconnection of the multiple capacitor banks appears electric arc re-lighting, the transitory phenomena are the same like with the others from the connection of bank's stage to another stage, already being in function, resulting big shocks of current and so, stresses produced by these effects.

With results that at the capacitor banks disconnection, generally, it would not produce very big stresses in the power systems if it would not appear electric arc re-lighting between the breaker's contacts and current snatches. Sometimes these desiderata are not fulfilled in the construction and function of the breakers because of generalising of the economic part of the breaker's construction, or because of realisation of non-performance breakers [1-4].

It results that the number of re-lighting and the overvoltage's and overcurrent's measure it alter in report with the disconnected bank power, in the idea the feeding circuit remains unchanged.

It can be realised disconnection without electric arc re-lighting, with the conditions to use breakers with dielectric rigidity (holding voltage) to grow more quickly then the growing speed of the oscillate recovering voltage. It answers very well at this request the breakers with SF6 and with vacuum. Also, the pneumatic breakers or with oil if are equipped with driving mechanisms which can assure high speed for opening the contacts [5-8].

How the breakers are subdued in exploitation to diverse normal states of function and of damage and how very often this requests technical and functional from one state are opposites to another state of function it is imposed in the next preoccupation in the view to perfect the construction and the function of these and in the same time the limitation at maximum of the electromagnetic stresses introduced in the power systems.

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STAŢII DE TRANSFORMARE ANTIGRIZUTOASE PENTRU EXPLOATĂRI MINIERE SUBTERANE

ING. PAULINA DIACONESCU – S.C. ELECTROPUTERE S.A.

În lucrare se prezintă activitatea S.C. ELECTROPUTERE S.A., Divizia Transformatoare, privind asimilarea staţiilor de transformare antigrizutoase, antideflagrante, principalele caracteristici ale echipamentului compus din transformatorul uscat propriu-zis, compartimentele aparatelor de medie şi joasă tensiune, soluţii constructive pentru carcasa metalică de tip antideflagrant.

Se menţionează preocupările de perspectivă în domeniul modernizării şi diversificării staţiilor, vizând realizarea noilor staţii de transformare în clasa H, la raportul de transformare 6 / 1,05 kV, cerute de industria minieră, ca urmare a modernizării unor exploatări miniere.

1. GENERALITĂŢI

Necesităţile privind asimilarea în ţară a diferitelor echipamente electrice în vederea înlocuirii celor aduse din import au permis dezvoltarea la ELECTROPUTERE, încă din 1975, a unei fabricaţii de serie de staţii mobile antigrizutoase necesare industriei miniere, alimentării consumatorilor din minele cu regim grizutos.

Împreună, atelierul proiectare transformatoare, atelierul proiectare aparataj şi fabrica de transformatoare au proiectat şi executat primele statii de transformare trifazate, uscate, în clasa F, construcţie antideflagrantă, echipate aparataj de conectare, măsură şi protecţie de puteri 250 şi 400kVA 6 / 0,4 kV.

Staţiile de transformare corespund IEC 76, STAS 6877 / 1,2 - 86 şi normelor miniere în vigoare, asigură protecţia antigrizutoasă ExdI şi gradul de protecţie IP 54 la carcasă şi cutii de borne, au fost verificate la încercările normale, cele specifice de explozie şi funcţionează cu bune rezultate în exploatarile miniere din ROMÂNIA.

Seria de staţii s-a diversificat prin asimilarea, în continuare, a noilor produse la raportul de transformare 6 / 0,69 kV, cu performanţe, construcţie metalică (carcasă antideflagrantă) realizate pe aceleaşi principii cu varianta de 6 / 0,4 kV.

În ultimii ani, am realizat la cererea beneficiarilor noştri, pentru creşterea siguranţei în exploatare şi variantele tuturor staţiilor de transformare cu un nul artificial de 10 A pe partea de joasă tensiune.

2. CARACTERISTICI TEHNICE ALE STAŢIILOR

Tabel 1

2.1. Puterea nominală	250	400	400	500
2.2. Raport de transformare la mers în gol kV/kV	6/0,4	6/0,4	6/0,69	6/0,69
2.3. Reglajul tens. Primare %	-5	-5	± 5	± 5
2.4. Pierderi la mers în gol W	1300	1500	1500	2750
2.5. Pierderi la sarcină W	2300	3100	3100	2600
2.6. Tensiune de s.c. la In şi 115°C temp. înfăşurărilor %	3,5	4	4	3