SYNCHRONOUS SWITCHING OF POWER SYSTEMS

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Abstract: - Synchronous switching is one subject that have gained a great deal of relevance not only because of their potential for increasing reliability and for making a contribution to improve the overall power quality of the electric systems, but also for economic reasons. These concepts can be instrumental in minimizing the use of auxiliary components, such as pre-insertion resistors, in reducing equipment wear and unnecessary maintenance and thus reducing the total cost of ownership throughout the full lifetime of equipment. In this paper, the problems of controlled switching, specially in medium voltage networks, will be presented.

Key-Words: - controlled switching, transient overvoltages

1 Introduction

Closing or opening the contacts of a electrical switches is normally done in a totally random fashion and consequently, transient current and voltage disturbances may appear in the electrical system[1,3]. Closing a switch or circuit breaker in a dominantly capacitive or inductive network results in inrush currents, which can cause problems for the protection system. Energizing transmission lines and opening the circuit breaker to interrupt short circuit currents are also good candidates for synchronous switching. The controlled switching is very effective in reducing of overvoltages and overcurrents transients.

Ideally and to obtain the greatest benefits, synchronous switching should be done using circuit breakers that are capable of independent pole operation. Independent pole operation is already a standard feature in circuit breakers that are rated above 220 kV and it is also used, under special request, for applications as low as 145 kV. However, for those designs where all three poles are operated in unison the implementation of controlled switching concepts will require the development of specially designed circuit breakers which are provided with suitable methods for staggering the pole operating sequences.

By the using of controlled switching it is also possible to diminish the asymmetric component of the multi-phases grounded or un-grounded short-circuits [1,2,4]. The oscillograms of voltage and current transients at uncontrolled and controlled switching for selected, above mentioned circuits, received from computer simulations or measured in real conditions, are presented [1]. Using EMTP/ATP program carried out the computer simulations. The results of simulations were used for establishing of permissible switching angle dispersion.

2 The Make-Break Time

Consistency in the making and breaking times of the circuit breaker is absolutely essential for successful implementation of all types of synchronous switching. However, considering the fact that a circuit breaker is a mechanical device and even though modern designs highly reliable, further improvement still is necessary. It is indispensable to closely analyze the mechanical and electrical properties of the design including contact velocity, contact opening time, contact closing time, minimum arcing time for different interrupting duties and current levels and cold gap voltage withstand capability. Furthermore, and in relation to the operating times, the effects of control voltage fluctuations, ambient temperature, tolerances of the mechanism's stored energy and operating wear must also be considered.

Of all the parameters that have been mentioned above the ones that have the greatest influence in the consistent timing of a circuit breaker are the ambient temperature, the level of energy stored in the operating mechanism and the control voltage level.

Modern SF_6 or vacuum circuit breakers have operating times at switching on or off operation with accuracy of control less than $\pm$ 1 ms, which is presented exemplary for SF_6 circuit breakers in Table 1. For the majority of analysed switched circuits the permissible switching angle dispersion may be equal to ± 2 ms or even up to ± 3 ms.

Tab. 1: Influences of ambient and control conditions on operating time accuracy

Parameters	SF_6 Circuit breakers			
	Hydraulic drive		Spring drive	
	open	close	open	close
Temperature over range - 40^0 C to + 40^0 C [$\mu s/^0$ C]	30	70	30	70
Control voltage over the range - 15% to + 10% [ms]	± 0.5	± 1.5	± 0.5	± 0.5

It is also quite evident that the control voltage exerts the greatest influence on the operating times. The parameter, in comparison to all the others offers better possibilities for enhancement and consequently it is where the major improvement would be expected. Possible solution are use a regulated power supply or capacitor discharge systems to provide the control power required for the supply of the control circuits energizing the operating coils. In addition the solenoid coils should be optimized to reduce the operating time range.

3 Synchronous Capacitors Banks Switching

For capacitance switching, the primary concern is not as much the interruption of capacitive currents because, due to the inherent characteristics of vacuum and SF_6 circuit breakers, the problems associated with restrikes, which were quite frequent with earlier technologies, have been greatly reduced and today indeed restrikes are a very rare occurrence.

On the other hand, failures are often reported which are the direct result of inrush currents and overvoltages that have propagated themselves into lower voltage networks causing damage especially to electronic equipment connected to the circuit.

In order to completely eliminate the overvoltages produced by the closure of a circuit breaker onto a capacitor bank it is required that there be a zero voltage difference across the contacts of the circuit breaker at the time where the contacts meet. Naturally this is not always possible simply because some deviation from the optimum operating conditions has to be expected. There are number of studies [1,2,5,6] that have shown that the overvoltages can be significantly reduced. It has been shown that the overvoltages can be kept within acceptable limits whenever the closing of the contacts is controlled so that it occurs within one millisecond either before or after the voltage zero point.

Some characteristic result of simulations and measurements results of transients voltages [1] are shown for uncontrolled and controlled switching of grounded single capacitor bank, are presented at Fig. 1a, Fig. 1b.

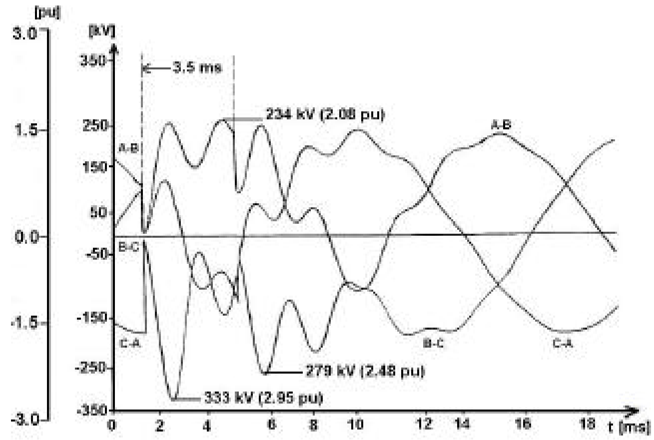

Fig. 1a: Transient overvoltages at switching of grounded single large shunt capacitor bank at uncontrolled energization

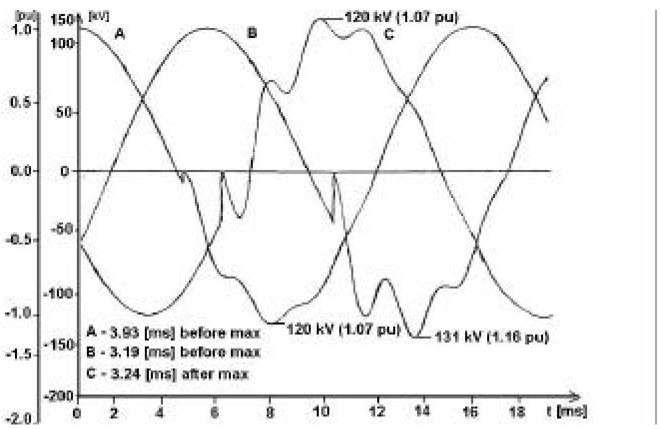

Fig. 1b: Transient overvoltages at switching of grounded single large shunt capacitor bank at controlled energization

4 Synchronous Reactor Switching

For reactor switching operations the basic needs are the opposite of those considered to be desirable for capacitance switching, that is closing the circuit is not important as is opening. Synchronized opening of the contacts in an application involving the switching of reactors should be considered for the purpose of reducing overvoltages that may be generated as the result of current chopping or reignitions that may occur during a normal opening operation (Fig. 2a, 2b). One benefit of synchronous opening of reactor circuits, especially those that use reactors for shunt compensation, is that it substantially reduces switching surge overvoltages.

Synchronous control for opening reactor circuits is not difficult to achieve since it is only necessary to separate the contacts at a time which is larger that the minimum arcing time required for that operation by that particular circuit breaker design. What is important is that the contact gap be sufficient to withstand the recovery voltage and that the contact separation be close enough to the minimum arcing time to reduce the possibility of current chopping.

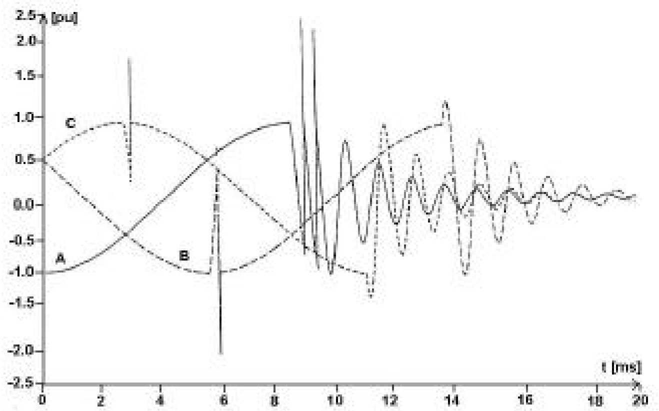

Fig. 2a: Transient overvoltages at de-energization of shunt reactor at uncontrolled energization

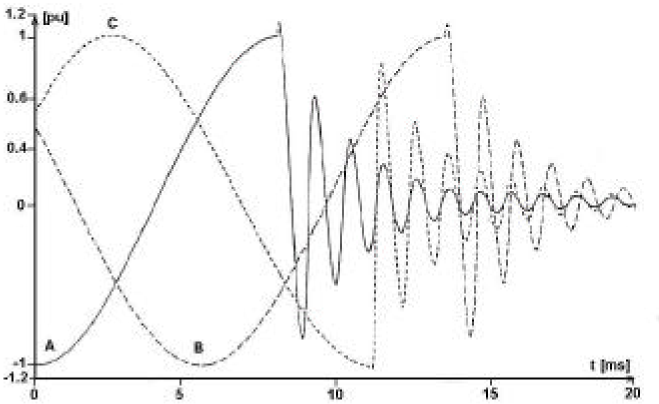

Fig. 2b: Transient overvoltages at de-energization of shunt reactor at controlled energization.

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5 Conclusions

The most convenient phases for controlled switching of any three phases circuit for diminishing of overvoltages and over currents is:

- at closing operation for limitation of overvoltages – at the moment of minimum voltage on the contacts of switching devices at the moment of contacts closing;
- at closing operation for diminishing of overcurrents; at the moment of maximum supplying voltage on the contacts of switching devices at the moment of contact closing;
- for limitation of overvoltages affected by restricting or reagnitions the moment of contacts separation of each phase should be just after zero of interrupting current.

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