Experimental System for Transient Stress Dimmision by Using Controlled Commutation

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***Abstract* - The controlled switching can be applied to any type of commutations. Now there are dedicated controllers which are used more often for the switching of the transport and distribution lines, of the small inductive loads, of the capacitors batteries, or the energizing the no load power transformers. The rate of decreasing of the dielectric rigidity and the mechanical dispersion of the switching on/off times qualifies the breakers to be able or not for controlled switching and give an optimum for different switching applications. The compensation of the waiting time is essential in order to obtain good performances, even for daily used breakers. The influence of the pause time on the driving mechanism is one of the mainsprings of the command errors. The paper presents an experimental system developed microcontroller Dallas (8051 family) used to controlled switching of various loads. The microcontroller programming take into account the controlled closing command. Closing time which is the target closing time is the sum between the delay of the command corresponding to the considered phase and the predicted closing time. Predicted closing time depends on the ambient temperature, the type of operating mechanism and pause time. Experimental system reduces the transient requests using the control of closing command.**

Keywords - *controlled switching; transient requests; experimental system*

I. Principle of Controlled Switching

There are several important circuit breaker applications where random closing or opening instants may lead to severe voltage and current switching transients. These transients occur in the main circuits, but may also induce transients in control and auxiliary circuits, as well as in adjacent low voltage systems.

The switching transients are associated with a variety of dielectric and mechanical stresses on the high-voltage equipment, and may cause gradual or immediate damage to the system or the equipment. Induced transients may lead to a variety of disturbances, e.g. in substation control and protection systems, computers and processors, or telecommunications.

Normal energizing of shunt capacitors, shunt reactors and power transformers may cause severe transients - high over-voltages, under-voltages, or high inrush currents. Upon de-energizing of shunt reactors, re-ignitions will occur, resulting in steep voltage surges (Fig.1).

The magnitude of the transients depends on the point-on-wave where closing or opening of the circuit breaker contacts occur. In a situation without controlled switching, sooner or later the switching instant will occur at the worst possible phase angle.

Controlled switching is a method for eliminating harmful transients via time controlled switching operations. Closing or opening commands to the circuit breaker are delayed in such a way that making or contact separation will occur at the optimum time instant related to the phase angle (Fig.2).

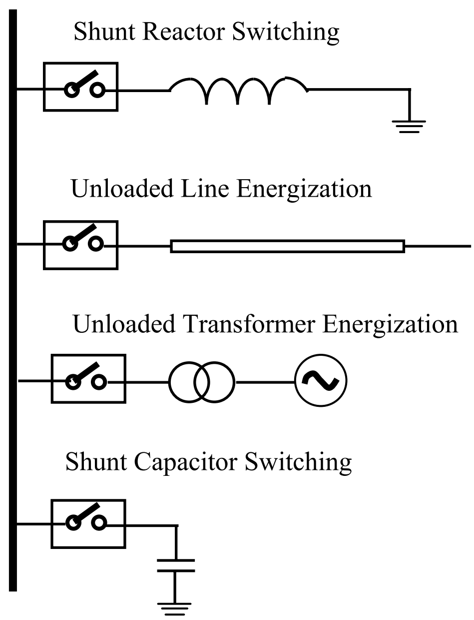

Fig. 1. Controlled Switching Applications.

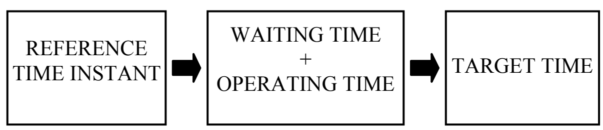

Fig. 2. The Principle of the Controlled Switching.

The following example illustrates the general operating principle of a controlled switching, for energizing a reactor. In order to avoid switching transients, the making instant in this case shall be at voltage zero [1].

For simplicity, only a single phase is considered (Fig. 3), where:

- TF = Time to detect final reference voltage zero;
- TV = Waiting time;
- TM = Expected make time of circuit breaker.

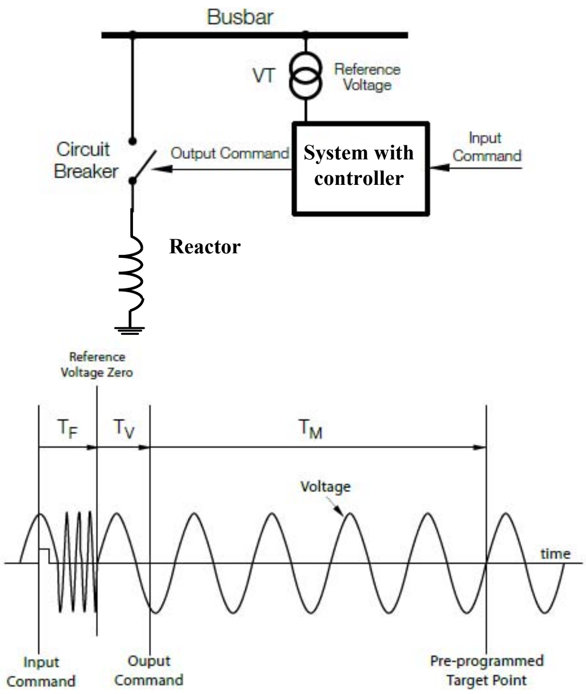

Fig. 3. Principle of a Controlled Switching for energizing a reactor

II. Testing Procedures and Conditions for Single Components and Integrated Systems

The basic conditions imposed to independent poles breakers refer to [2]:

- The negative slope (rate of decreasing) of the dielectric stress (RDDS);
- The mechanical dispersion of the switching on / off times, depending on various conditions;
- The dependence between the pause time and operation time.

The rate of decreasing of the dielectric rigidity and the mechanical dispersion of the switching on/off times qualifies the breakers to be able or not for controlled switching and give an optimum for different switching applications. The compensation of the waiting time is essential in order to obtain good performances, even for daily used breakers.

The controller must be able to implement the following functions [3]:

- Compensation of the waiting time face to the increasing of the closing time due to the pause time;
- Conditional compensation of the turning on / off times depending on various conditions (ambient temperature, command voltage, hydraulic pressure);
- Adaptive compensation of the changes of the turning on/off times due to the long term ageing.

The influence of the pause time on the driving mechanism is one of the mainsprings of the command errors.

Till recent, the most controllers did not compensate the pause time.

Fig. 4 shows the dependence of the closing time versus the pause time for the resort mechanism specific to 145kV-362kV systems. Fig. 5 plots the same dependency for hydraulic mechanisms specific to 300kV systems [4].

These characteristics were evaluated for cycles C-O-C-O after pause times of 2, 4, 8, 16, 64, 128, 256, 720 hours. The resort mechanism was greased on the moving parts. It has a very low dependency of the closing time by the pause time, up to 1000 hours. The experiments with a classic hydraulic mechanism show the increasing of operation (closing) time can be noticed for pause time of few hours. For pause time greater than 70 h, the closing time increases by 2 ms. The pause time must be continuously compensated for pause times up to 100h.

The most controllers have conditional compensations which are able to adjust the waiting time following the changes of the opening/closing times due to the ambient temperature, command voltage or hydraulic pressure.

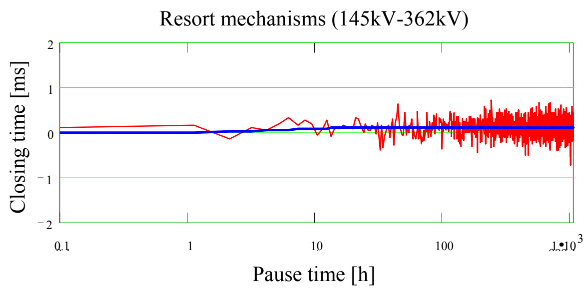

Fig. 4. Closing Time for Resort Mechanisms.

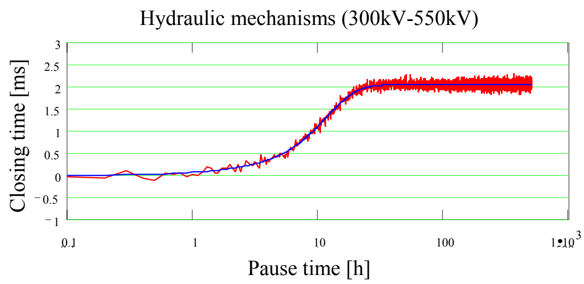

Fig. 5. Closing Time for Hydraulic Mechanisms

The variations of the turning on / off times of a 145kV independent poles gas breaker (resort mechanism) by the control voltage and ambient temperature were studied. The dependency of the closing / opening time on the control voltage and temperature were measured for 40 maneuvers. Fig. 6 plots the deviations of the closing/opening time by the average values for different ambient temperatures [5].

The figures show that, by using the controlled switching, the error on the desired opening / closing time can be reduced below 1 ms.

The differences by the typical switching time can be represented as a surface. This surface can be stored in the controller's memory as a common characteristic of a specific breaker type. This is possible because the average opening/closing time have low variations due to the manufacturing dispersions.

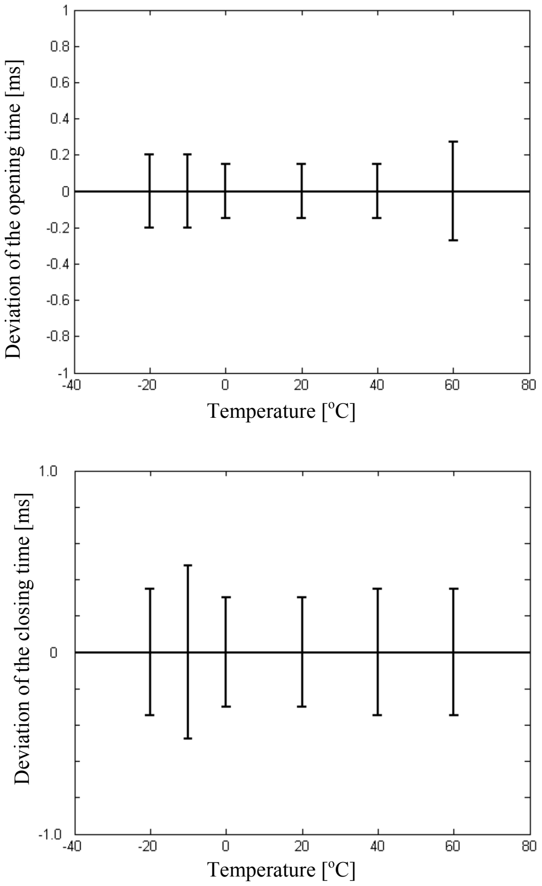

Fig. 6. Closing/Opening Time for Different Temperatures

The gas breakers generally imply, during opening / closing operations, sliding parts (contacts, gaskets). Consequently, the operation characteristics are strongly influenced by the changes of the friction forces due to the ageing and fraying. As the changes are slow, the adaptive control can effectively compensate the deviations of the operation times due to multiple maneuvers. The effects of the adaptive control depend on the number of maneuvers previous supervised and by the weight factors. These parameters are determined following a deep research of mechanical endurance tests.

Fig. 7 shows the typical deviations of the closing time, measured without and with adaptive control, for 1500 maneuvers of a 145kV gas breaker (resort mechanism) [4]. The variation of the closing time is given as the difference between the estimated closing time and the effective one. Even the closing time is greater when the number of maneuvers increases, this influence can be effectively be compensated quite precisely by the mean of the adaptive control. If the controller is able to detect the closing instant by measurement of the current in the principal circuit, the rate of decreasing of the dielectric stress can be also be compensated by adaptive control.

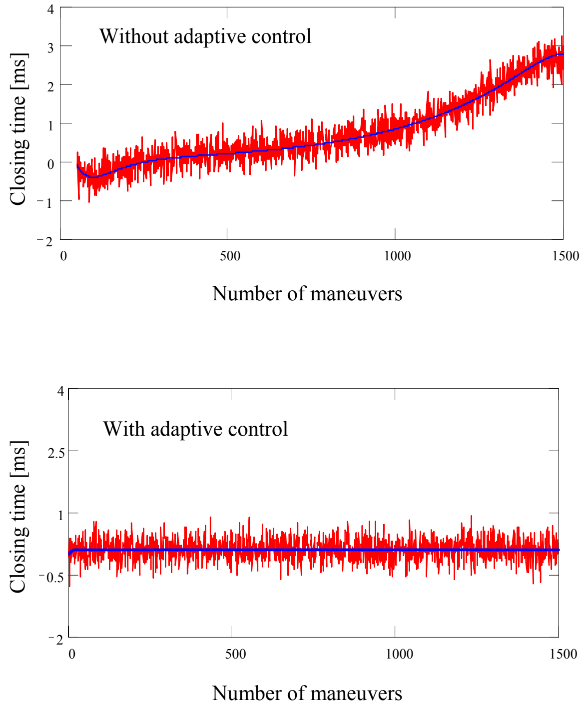

Fig. 7. Closing Time with and without Adaptive Control

Closing Order for controlled switching is calculated depending on the type of locking mechanism, ambient temperature and the number of maneuvers (Fig.8).

Timing chart for controlling the closing depends on the target closing phase is presented in Fig. 9.

The paper presents an experimental system used to control switching of various loads. The rate of decreasing of the dielectric stress and the mechanical dispersion of the switching on/off times qualifies the breakers to be able or not for controlled switching. The compensation of the waiting time is essential in order to obtain good performances, even for daily used breakers.

III. The Experimental System

The experimental system implies two main parts: hardware (sensors, transducers, A/DC, serial transmission) and software (field module programming, transmission protocols, user interface) [6].

The hardware part of the system is centered on the Dallas micro-controller DS87C550. This type of micro-controller is code fully compatible with the 8051 family micro-controllers, being equipped with many integrated peripherals that make it suitable for embedded applications. More than that, being equipped with the high speed core specific to the Dallas micro-controllers, the performances achieved by the hardware subsystem based on this module make it very suitable for the on-line monitoring of the high speed electrical equipments.

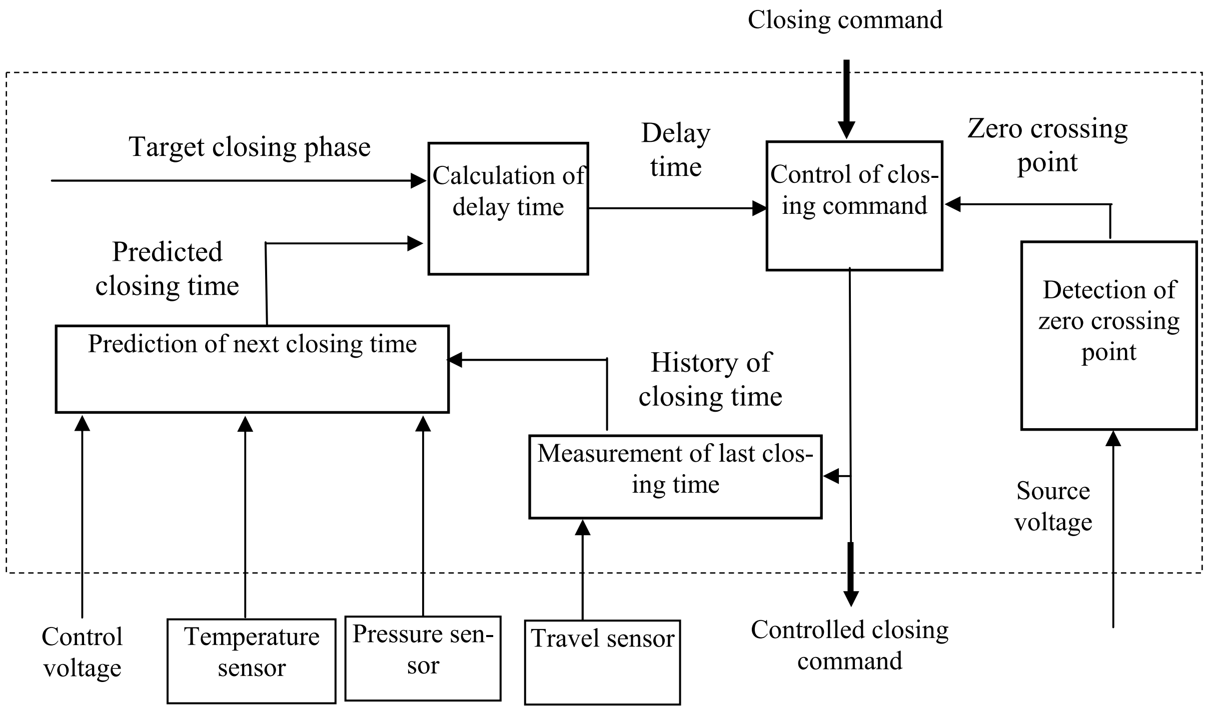

Fig. 8. Controlled closing command

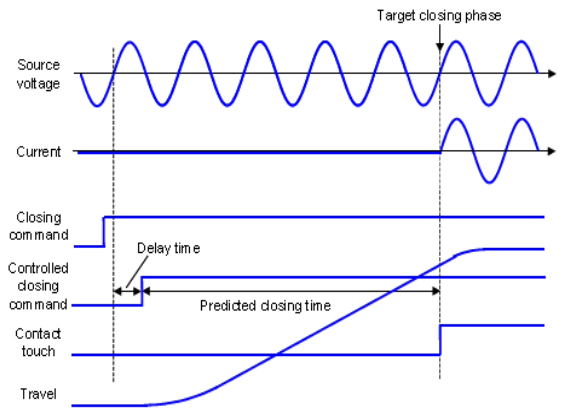

Fig. 9. Timing chart of controlled closing

The acquiring and transfer module consists of the blocks: Sources, Controller, Local console, Inputs, Outputs and Serial communication interface. By the way of three precise voltage regulators, the Sources block supplies the regulated voltages to the micro system. The Controller block is the core of the module and consists of the controller itself, the full duplex RS485 serial interface, connector to the 7 digits display, digital open collector output which can be used for commanding a power element (relay), non-volatile serial EEPROM (Fig. 10).

For the fastest and efficient behaviour to the user's demanded functions, the acquiring and transfer module was programmed in assembler, by using the complex interrupting system of the controller [7].

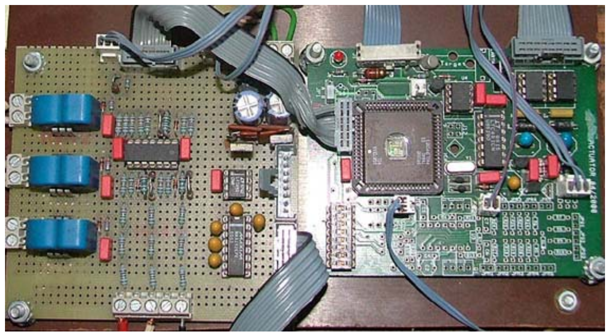

Fig. 10. The experimental system

The tasks performed by the main program are depicted in Fig. 11, where:

Tcp - Predicted closing time;

Tcl - Last closing time;

Td – Delay time;

Tzero - Zero crossing point.

The microcontroller programming take into account the controlled closing command (Fig. 8) and timing chart of controlled closing (Fig. 9.). Closing command depends on the delay time and zero crossing point.

Closing time which is the target closing time is the sum between the delay of the command corresponding to the considered phase and the predicted closing time. Predicted closing time depends on the ambient temperature, the type of operating mechanism and pause time.

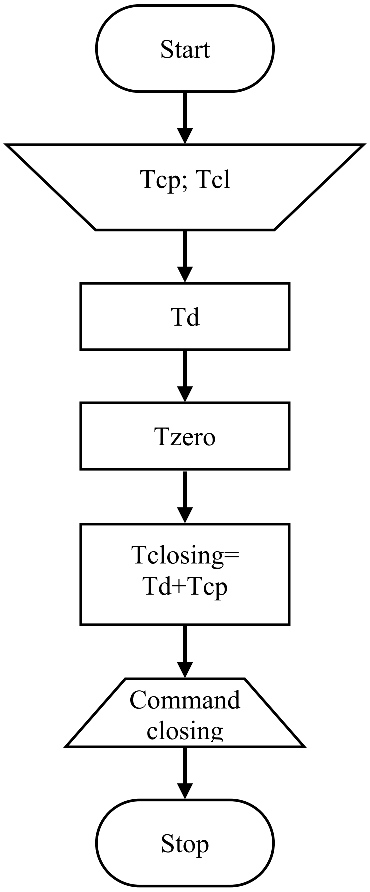

Fig. 11. The flowchart of the main

IV. Conclusions

The developed experimental microcontroller system performs the functions corresponding to the controlled commutation: determines, depending by the type of load, the precise instances for switches control in order to reduce stress on switching and compensates the variations of the switching times of the circuit breaker operating mechanism.

In practice, the control of the reconnection must take into account the delay introduced by the beaker actuation mechanism, specific for each type of mechanism. This delay is at its turn, dependent on the pause time after the last actuation, on the ambient temperature and on the total number of actuation maneuvers done during the life time.

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