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Connection time study for 400 kV circuit breakers with SF6

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Connection time study for 400 kV circuit breakers with SF6

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Abstract. This paper presents the calculation of the time for the SF6 circuit-breaker operation by studying the voltage characteristic before connecting. Simulated on the basis of the switch characteristics and the factors that interfere with the time, i.e. the temperature and supply voltage of the breaker coil. Connecting the circuit breakers has a very important role in eliminating the vibrating and electrodynamic loading regimes in high voltage electrical networks.

1. Introduction

The SF6 switches are among the used switches that are reliable. The choice of when to connect is very important in the switching process, so in our case it is considered that the optimal moment is at the maximum voltage of the bar. For our case, it is considered a switch model in a three-phase network and one phase is studied.

The switching time for the circuit breakers is calculated by a program installed in the Bay Control Unit (BCU) of the control unit located in each cell of the power station and receives the command from the user to close or open the switch at the point on the voltage or current taken as a reference. The method is also called synchronous switching or controlled switching [1-3]. Switching control provides an efficient solution taking into account the current values, the control unit optimizes the switching operations of the switch using the instantaneous voltage curve or the instantaneous current curve [4].

The operational principle of the OPEN operation is the same as for CLOSE with the difference that it can be used as a reference signal for a zero-pass current and that the recharged currents [5], [6] are monitored. The main advantage of this method is the reduction of the transient switching effects, with implicit reduction of voltages in the system and its equipment [7].

Closing: The time that passes between the electrical control emitted by the shut-off switch and the firm closing of the contacts at all switches of the switch is the closing time. The process of extinguishing the electric arc in the circuit breaker can cause a current flow that can rearm the arc during the arc-off period. The time elapsed between the command emitted by the circuit-breaker and the occurrence of the electric arc (starting current) at the first pole of the switch is considered the zero point (time origin). The switching process for the three poles of the circuit breaker must be viewed separately for switching control. To study the switching process, we define the following times:

- Closing time: The time elapsed between the electric switch at the pole of the breaker in question and the closing of the contacts (galvanic) in the circuit of the switch.
- Working time: The time elapsed between the electrical command at the pole of the circuit breaker (starting current) and the electric arc pole of the circuit breaker.

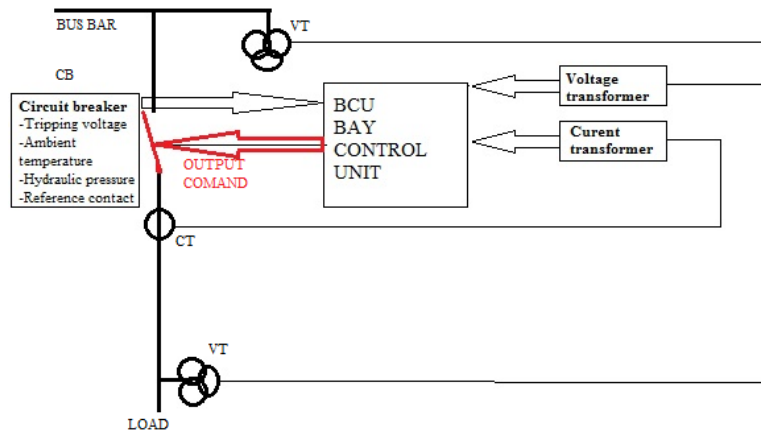- Time pre-arcing: The time at which the arc burns at the switch's pole during closure.

Figure 1. Switching Block Diagram [8]

2. The proposed solution

2.1. Mathematical model
For the study, one-phase system was used U=8,6 V , ɸU=-0.34 rad, f=50Hz, I=3A, ɸI=1.24 rad

$$u(t) = \sqrt{2}U sin(2\pi ft + \phi U) \tag{1}$$

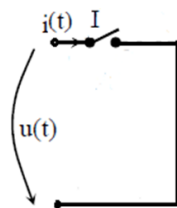$$i(t) = \sqrt{2}I sin(2\pi ft + \phi I) \tag{2}$$

Figure 2. The monopolar scheme for the studied circuit breaker

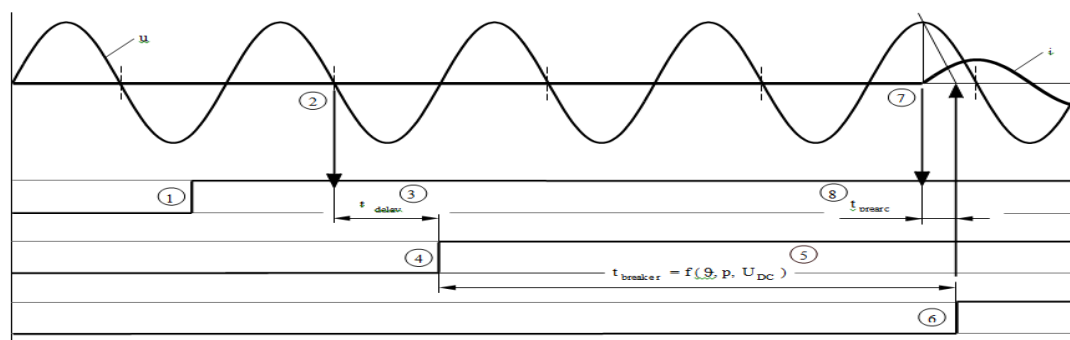### 2.2. Time model
The time model is shown in Figure 3.

Figure 3. Closing operation of circuit breaker with a control system [9]
1 - Closing command
2 - Identification of the zero point of the stresses
3 - Delay time 4 - Circuit breaker control 5 - Closing time
6 - Touch contact 7 - Starting current 8 - Pre-arcing time

2.3. Calculation of time coefficients for switching the studied switch
Calculation of time coefficients dependent on:
   tTemp=f(T) depending on ambient temperature
   In Table 1 is presented the temperature dependent coefficient.

Table 1. Time-dependent temperature-dependent coefficient [10]

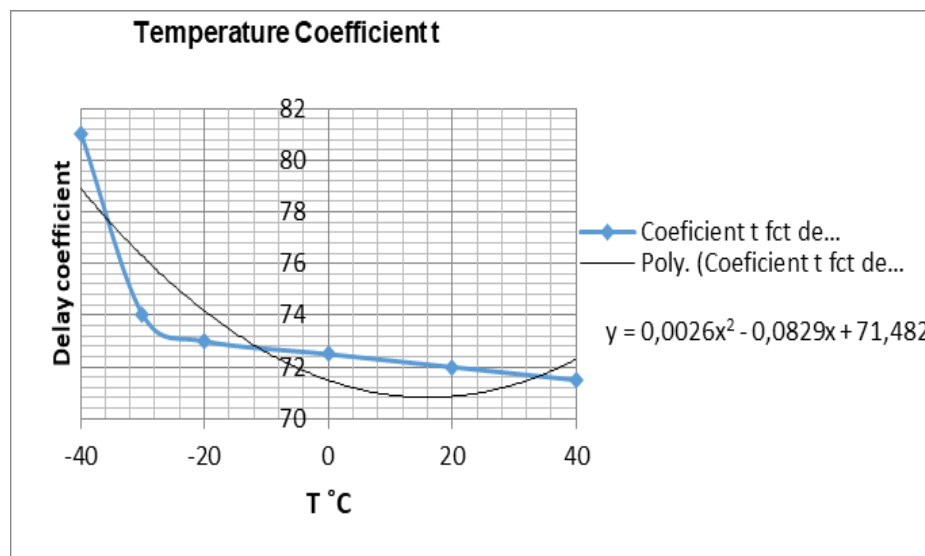| T[°C]	t(T)(ms)
40	71.5
20	72
0	72.5
-20	73
-30	74
-40	81

Figure 4. Evolution of the time factor due to temperature when switching on the circuit breaker

   Since the switch operates under normal conditions, ie the temperature within the range of 0°C + 40°C, we can approximate this coefficient to 72 milliseconds for the closing operation.
   tUDC =f(UDC) depending on the DC voltage (d.c.) Unom = 220V (d.c.) is the nominal voltage.

Table 2. Coefficient of time for U-auxiliary power supply coil (d.c.)

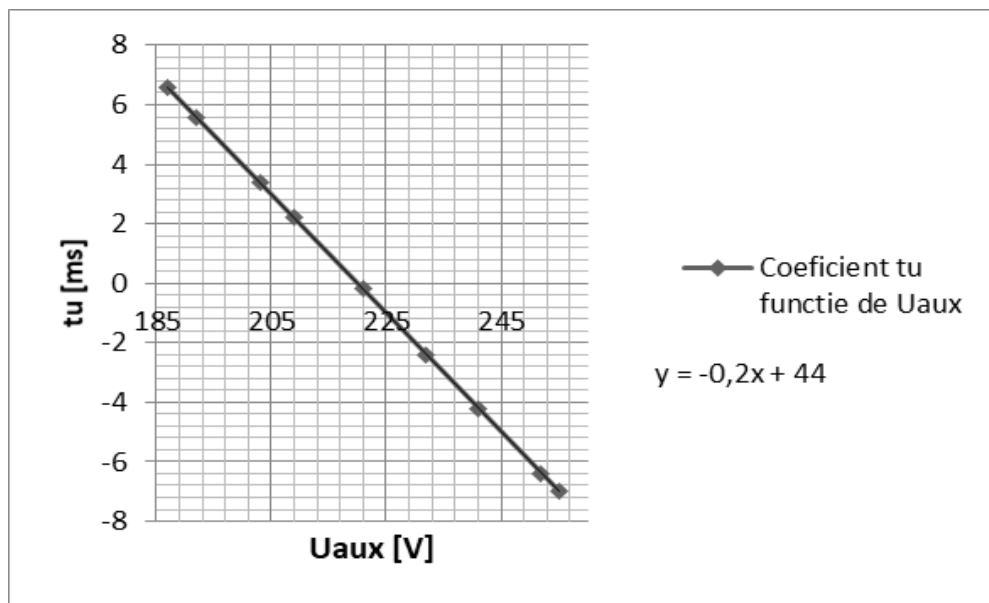| U (measured)[V]	Coefficient
U control (V)	*Coef (msec)*
187	6.6
192	5.6
203	3.4
209	2.2
221	-0.2
232	-2.4

Figure 5. The evolution of the time factor that depends on the auxiliary voltage of d.c.

These values are measured by varying the supply voltage of the circuit breaker and measuring the switch-off time of the circuit-breaker. As can be seen from this graph, the coefficient of time dependent on the supply voltage supply voltage of the supply coil has a linear characteristic and has a null value of Unom = 220 V and decreases with increasing the voltage value.

This voltage must be in the range Umin = 187 V and Umax = 255 V if it exceeds this range and it is signaled by the monitoring relays in the internal d.c. services.

Time factor that depends on the pressure of the hydraulic agent (if the circuit breaker is operated with hydraulic oil actuators).

tP=f(P) depending on pressure Pnom=330 bar
In Table 3, the values of the coefficient according to the pressure of the hydraulic agent are shown.

Table 3. Values of the coefficient according to the pressure of the hydraulic agent.

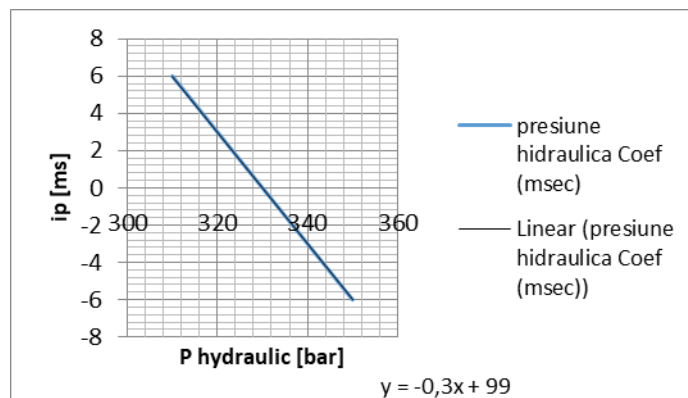| P hydraulic (bar)	Coef (msec)
310	6
316	4.2
321	2.7
326	1.2
333	-0.9
337	-2.1
342	-3.6
346	-4.8
350	-6

Figure 6. The evolution of the time factor according to the Hydraulic Pressure

The graph shows a linear evolution y = -03x + 99 with downward slope to increase the pressure of the hydraulic agent. These values of the closing time of the breaker are taken from the circuit breaker's technical sheet [10]

3. Graphics simulation and calculations

The logical diagram for the simulation of switch circuit breaker is shown in Figure 7. Graphics and simulation were done using Geogebra 4.4 and Excel.

4. Conclusions

The simulation is very useful in studying the operation of a high power circuit breaker [10-12]. Based on the results obtained, the following conclusions were identified: simulating the closing time for SF6 circuit-breakers depends largely on the switch type; for each type of switch, its characteristics must be raised depending on the temperature, the supply voltage with d.c. the actuating coils, and the hydraulic agent pressure; since the switch operates under normal conditions, ie the temperature within the range of 0 ° C + 40 ° C, we can approximate this coefficient to 72 milliseconds for the closing operation; to check these times, it is necessary to use auxiliary contacts that copy the position of the circuit breaker contacts very fast and accurate; the calculation algorithm for the connection time is simple. It is all about calculating the seven time points and applying the command to the switch's coil as soon as possible. Measurement with high precision by means of existing transducers in the temperature and voltage. The simulation was done for a single phase, in case the circuit breaker control is monopolar, then the phase shift command must be transmitted in phase to the studied phase with a certain calculated delay.
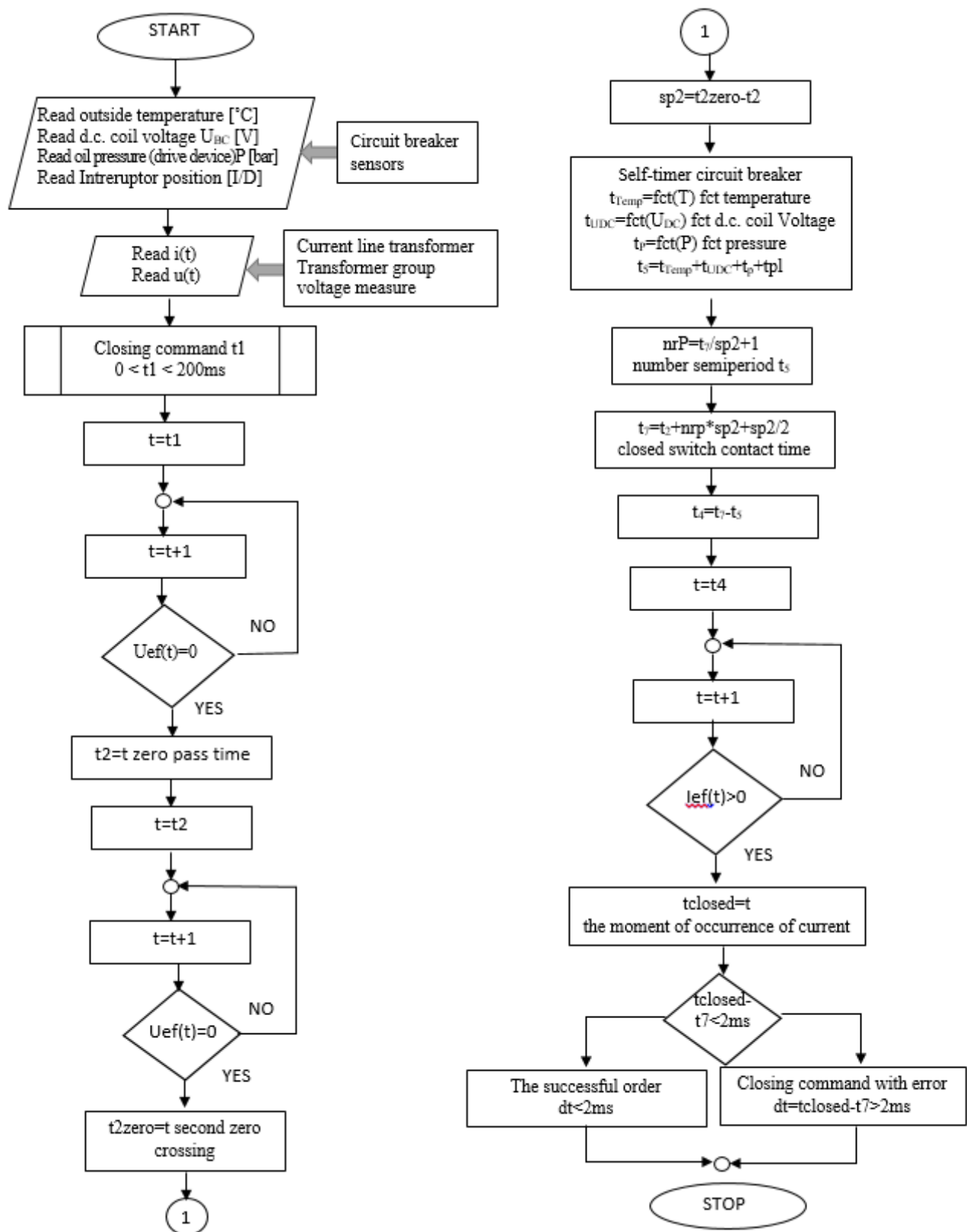
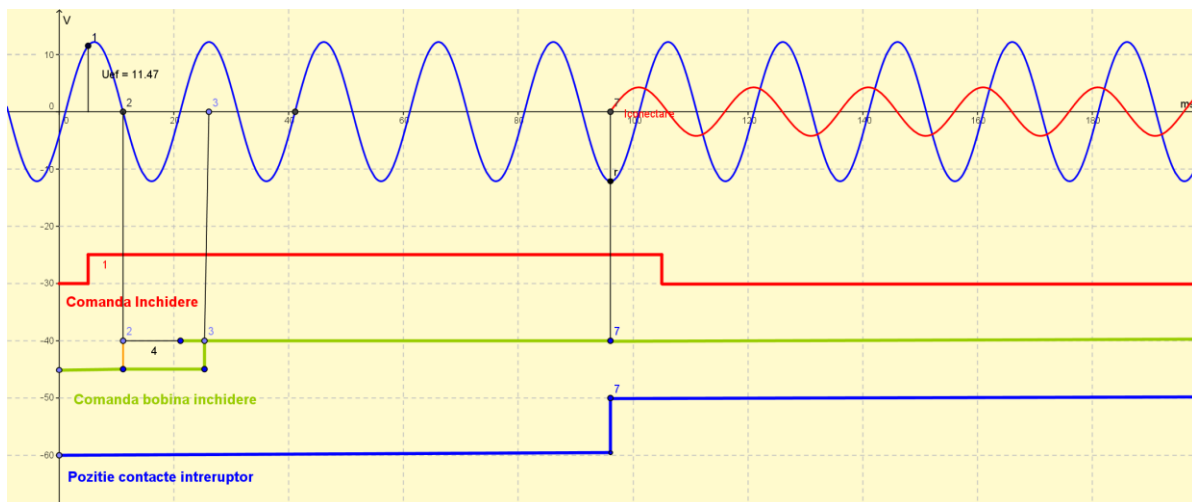**Figure 7.** Logic circuit diagram of the circuit breaker

Figure 8. The single-phase connection feature for t1 = 5ms

Table 4. Calculation of time coefficients for connection characteristic t1 = 5ms

U	8.6	V		
f	50	Hz		
ϕU	-0.34	rad		
Temperature	18	tT	71	ms
U cc	238	tucc	-4	ms
P bar	325	tp	2	ms
		t5	69	ms

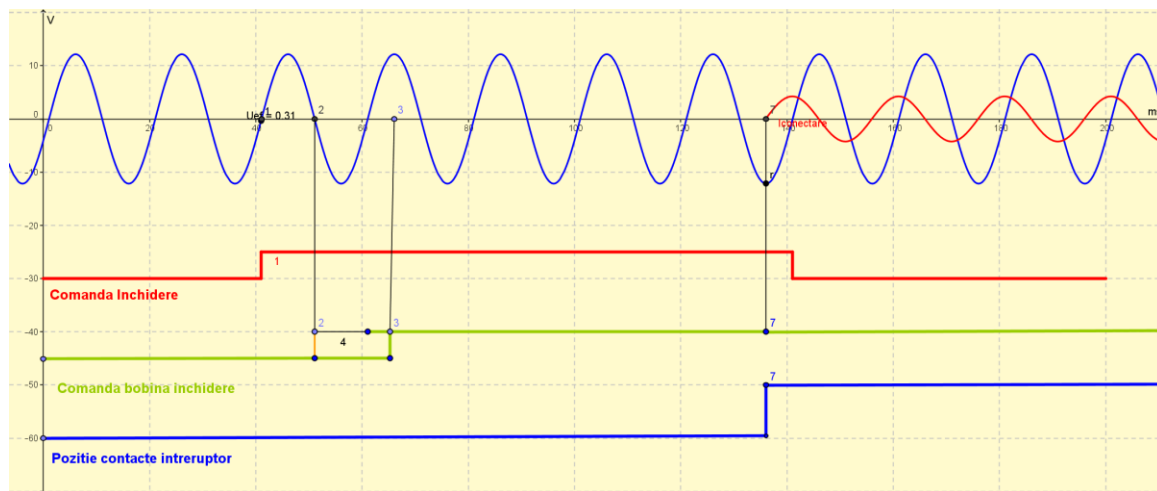|	t1	5		ms
		6	12.158176	ms
		7	11.66022	ms
		8	10.02088	ms
		9	7.4006272	ms
		10	4.0559489	ms
	t2	11	0.3142462	ms
		12	-3.4582172	ms
		13	-6.8921662	ms
		14	-9.6514619	ms
		15	-11.466005	ms
u(t)=0	t2=	11		ms
t=f(T,U,P)	t5=	69		ms
SP2=1000/f/3	sp2=	10		ms
nrp= t5/SP2 +2	nrp=	8		ms
t7=t2+nrp*SP2+Sp2/3	t7=	96		ms
t4=t7-t5	t4=	27		ms
t3=t4-t3	t3=	38		ms

Figure 9. One-phase connection characteristic for t1 = 41ms

Table 5. Calculation of time coefficients for connection characteristic t1 = 41ms

U	8.6	V		
f	50	Hz		
φU	-0.34	rad		
Temperature	23	tT	71	ms
U cc	242	tucc	-4	ms
P bar	330	tp	0	ms
		t5	67	ms
t1	**41**			ms
		42	3.4582172	ms
		43	6.8921662	ms
		44	9.6514619	ms
		45	11.466005	ms
		46	12.158176	ms
t2		47	11.66022	ms
		48	10.02088	ms
		49	7.4006272	ms
		50	4.0559489	ms
		51	**0.3142462**	ms
u(t)=0	t2=	51		ms
t=f(T,U,P)	t5=	67		ms
SP2=1000/f/3	sp2=	10		ms
nrp= t5/SP2 +2	nrp=	8		ms
t7=t2+nrp*SP2+Sp2/3	t7=	136		ms
t4=t7-t6	t4=	69		ms
t3=t4-t3	t3=	120		ms

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