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PARAMETERS AND CHARACTERISTICS ANALYSES IN CHOOSING HIGH-SPEED AUTOMATIC TRANSFER SWITCH (HSATS) DEVICES FOR OIL AND GAS PLANTS POWER SYSTEMS

АНАЛИЗ ПАРАМЕТРОВ И ХАРАКТЕРИСТИК ПРИ ВЫБОРЕ УСТРОЙСТВ БЫСТРОДЕЙСТВУЮЩЕГО АВТОМАТИЧЕСКОГО ВВОДА РЕЗЕРВА (БАВР) ДЛЯ СИСТЕМ ЭЛЕКТРОСНАБЖЕНИЯ ПРЕДПРИЯТИЙ НЕФТЕГАЗОВОЙ ОТРАСЛИ

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Abstract. High-speed automatic transfer switch (HSATS) has been designed to enhance security of Essential Service supply and to provide dynamic stability of complex electromotor load in cases of short-run disturbance of power supply input. Its performance is based on continuous monitoring of line-to-earth voltage and current values at bus bars of two distributor gear incoming units, their transformation into complex effective voltage and positive-sequence current values as well as software processing of measurement values [6].

The device appears to be only one component of HSATS system which apart from the start-up system itself comprises also current and voltage transformers as well as power cutoff switches, their number depending on distributor gear circuit. While among these only power cutoff switches can influence transfer speed. This fact determines the necessity to use modern ballistic breakers that provide standby uninterrupted power supply system (UPS) total switching time taking into consideration starter action time thus providing full load performance independent of its composition.

The article covers the results of the differential analyses of parameters and characteristics of HSATS most frequently used at oil and gas plants. The main problems arising in the process of such devices operation are studied.

Аннотация. Устройство быстродействующего автоматического ввода резерва (БАВР) предназначено для повышения надежности электроснабжения ответственных потребителей и обеспечения динамической устойчивости

комплексной электродвигательной нагрузки при кратковременных нарушениях электроснабжения. Его работа основана на непрерывном мониторинге величин фазных напряжений и токов на шинах двух вводов распределительного устройства, преобразовании их в комплексные действующие значения напряжений и токов прямой последовательности и программной обработке результатов измерений [6] .

Это устройство является лишь одной составляющей системы БАВР, в которую помимо самого пускового устройства также входят трансформаторы тока и напряжения, а также силовые выключатели, число которых определяется схемой распределительного устройства. При этом на быстродействие переключения на резервный источник питания, среди перечисленных, могут оказывать влияние только силовые выключатели. Это обуславливает необходимость применения современных сверхбыстродействующих выключателей, обеспечивающих полное время переключения на резервный источник, с учетом времени срабатывания пускового устройства, что позволяет обеспечить устойчивость функционирования всей нагрузки вне зависимости от ее состава.

В работе приведены результаты сравнительного анализа параметров и характеристик устройств БАВР, наиболее часто применяемых на предприятиях нефтегазовой отрасли. Рассмотрены основные проблемы, возникающие в процессе эксплуатации этих устройств.

Keywords: high-speed automatic transfer switch, software, configuration, oscillogram.

Ключевые слова: устройство быстродействующего автоматического ввода резерва, программное обеспечение, конфигурация, осциллограмма.

Introduction of HSATS complexes in oil and gas plants power systems has decreased the damage caused by power interruption, and enhanced industrial and energy security at plants. Nowadays, alongside with indisputable advantages, HSATS devices also have a number of drawbacks which can be disclosed during operation and testing in working conditions. Let’s analyse the main parameters and characteristics used in choosing HTATS devices through the example of those most commonly used in oil and gas plants power systems:

- microprocessor-based starter HTATS device «Bresler – MPEI MBTU 01.07-071»;
- HTATS of ABB company’s SUE3000 type.

Table 1 presents differential characteristics of such devices [1]. In order to define the sub-station emergency mode the starting HSATS device applies the following criteria:

- U_{min} – voltage watch at the collecting bar, V;

- δ_{12} – phase angle between collecting bar voltage and emergency source, degree;
- P+jQ – direct sequence active power set point.

If power changes direction from the load to the supply, HSATS operation is triggered.

- I_{min} – undercurrent set point. In case the set point is triggered, HSATS is blocked down in the same manner as direct sequence voltage changes direction, A;
- I_{max} – peak current set point. When triggered, leads to HSATS operation inhibition, A.

Table 1. HSATS devices comparison

HSATS Type	Criteria used by a starting device of a substation emergency mode self-maintained identification					Synchronous switching moment determination	HSATS total operating time, ms	Power presence	Asymmetric short circuit operation
	I_{max}	U_{min}	δ_{12}	P+jQ	I_{min}				
Bresler	-	+	+	+	+	+	40-80	-	+
SUE3000	-	+	-	-	-	+	50-300	+	-

For the SUE3000 device only those criteria for emergency operation detection presented by the supply are indicated that are implemented in the HSATS block itself exclusive of the input protection unit signal account.

The microprocessor-based starter device HTATS “Bresler – MPEI MBTU 01.07-071” is designed for the back supply high-speed turn-on at 6-10 kV sub-stations with high-voltage motive pressure (synchronous SM and asynchronous AM motors). Inductive dynamic acceleration device based on the condenser bank located in the HSATS breaker cell, stores up energy in sub-station normal operation and with the help of the control device, on command from HSATS, it imposes overvoltage on trip (close) coils of the switches [5].

By means of the inductive dynamic acceleration device the closing and opening time of the switch is shortened twice. But the acceleration of the closing (opening) time of the switch with the help of overvolting leads to additional wear and tear and loss of life of the switch. There is no description of the underlying logic of the device in the engineering documentation, which doesn’t allow to assess the HSATS operation to the full. The work with the oscillograms of the device can be performed only using Bresler software as other widely-spread viewing programs don’t support the oscillograms saving format.

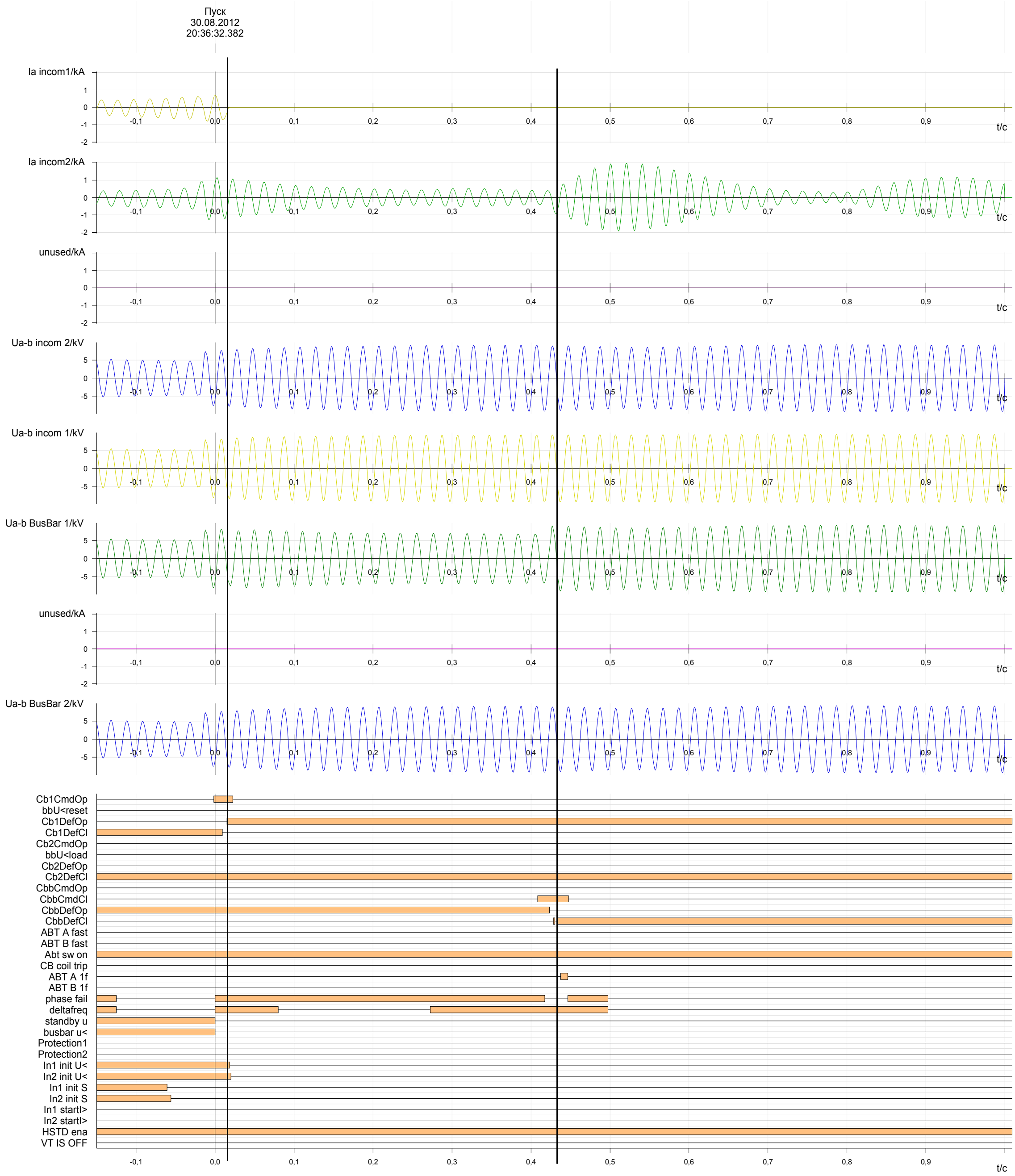

Figure 1. SUE3000 HSATS switch in case of the coincidence of the first phase

The high-speed switch device SUE3000 solves the problem of users' uninterrupted operation in case of power interruption by the quickest possible switching to stand-by input inclusive of diverse physical factors. As a result of the device onset both bus bar sections become connected to one and the same feeder. After the broken down feeder is restored the reconnection is carried out by hand [7].

There are four ways to switch the SUE3000 device:

- quick switch;
- first phase coincidence switch;
- rest potential switch;
- time switch.

Quick switch is an optimum switch mode which, in case of fault conditions, provides minimum loss of supply time. In cases when the network status doesn't allow using such a mode, slower switch modes are used. Unconditional logic registered in the HSTD (High Speed Transfer Device) block switches sections with a definite time delay, different from HSATS and standard ATS operation time. Figure 1 shows the sections switch by the SUE3000 device oscillogram in case of the first phase coincidence. The oscillogram shows that the time between Input №1 turn-off and the bus tie switch turn-in made 425 ms. Such operation mode affects motive stress consistency.

The SUE3000 device controls only each section stress, and it can become distorted in case of nearby faults. When there is no motive stress at the distorted section, the device doesn't switch due to absence of synchronization conditions [7].

New SUE3000 and REF542plus security units software versions are issued almost every year, that's why the organizations modernizing ABB equipment face difficulties. Substations built once a year or more rarely use different security units software versions. A newer updating version can be used to open older versions configurations but the change in logics or connections with earlier issued security units leads to program error. Thus, only one security device type accumulates several service program versions which leads to overloading of operating computers data storage devices and operating personnel' faults.

Modern HSATS devices are constructed on the basis of microprocessor-based relays that also have their drawbacks.

1. The ways electromagnetic disturbances from the power line influence microprocessors operation are the following:

- sudden loss of operating power supply during relay operation caused by overcharge or short circuit in the network, circuit breakers operation in the operating power supply circuit, lightning hits in power lines, broken wires etc. Such failures can lead to main memory on-going work interruption, microprocessor deadlock, and sometimes to complete loss of data unless special organization measures for relay power supply without failures are taken.

- electromagnetic noise or interference in supply circuits and in relay input circuits. Such interference can be caused by various factors and phenomena such as commutating or atmospheric overvoltage, transmitter radiation or heavy industrial equipment, voltage unsinusoidality. There are cases in microprocessor relays operating practice when a usual cellphone became a source of the emission which disrupted microprocessor relay normal operation [3];

- asymmetrical conditions in the network as well as conditions connected with voltage falls and ongoing voltage depression (lasting several seconds or more). Such conditions take place in case of high monophase capacity, compressors large-power motors starting up etc., as well as in case of power shortage in an electric power system in crush hours. Complex microprocessor-based relays are usually supplied with supply equipment capable of providing circuit elements with a necessary voltage level even in case of low sags. But in simpler relays such conditions lead to their proper operation disorder. And such disorder sometimes leads to very severe accidents in the network as microprocessor operation at degraded voltage supply level becomes absolutely unpredictable;

- networks overvoltage caused by load drop, or momentum switching overvoltage which get into a relay through supply mains thus leading to relay inner elements damage and its complete failure. Of course, there are international standards which list requirements to protect relays from all there effects, and relay designers take special measures against them. However, experience has shown that it by no means always shields even leading world companies' relays from damage.

2. Microprocessor-based relay protection systems, especially the complex ones, don't always run properly in case of serious emergency, and they by no means always can detect transient phenomena properly and timely. Failures and cases of complex microprocessor protections improper operation under actual operating conditions are rather often in practice. And if such relays are checked at a usual laboratory bench when there are standard signals at its inputs, they will operate accurately and safely. The problem is that at a laboratory bench it's impossible to imitate all the possible signal combinations and distortions that can occur in reality.

3. A microprocessor-based relay handles input values discretely. It "grips" current input values, buffers them, then grips one more input values set in a definite time term, and compares it with the buffered input values set. If the second set turns out to be identical to the first one, the input values are sent to microprocessor for processing. In emergency transient states a microprocessor has to process large amounts of data in real time mode together with quick and considerable changes of input values, definite time is needed to do this (sometimes, hundreds of milliseconds). More than that, if the situation has changed as late as after the microprocessor start (for example, single phase-to-earth fault changed to double-line-to-neutral fault, then to three-phase ground fault), the running computational process discontinues and all the measurements start from the very beginning [4].

4. There are big differences between electrical-mechanical and microprocessor relay behavior determined by the difference in their susceptiveness to harmonic components of the measured currents and voltage, current transformers saturation, input signal harmonicity distortion. It's known that at short circuit high ratio current transformers strongly distort the curve of the input current coming to the relay input. Drop in operation accuracy problem is important for relays of all types including electrical-mechanical ones. But the mechanical moment put on by the latter ones is proportional to the magnetic strength square created by the operating current. Such relays respond to the current root mean square which also includes harmonics that can

be found in the current. But most microprocessor-based relays use digital filters to quickly expand the input current curve in a Fourier series and extract only the main harmonics; the process is based on a so-called “fast Fourier transform”. Such operating principle doesn’t take into account those higher harmonic component of the current (voltage) that contribute greatly to total current (voltage) in transient states, in cases of emergency, when power transformers are turned on etc. As a result, differential microprocessor-based relays and distance relays respond to injected signals differently than electrical-mechanical ones. And as harmonic structure and amplitude are random values depending on fault location and type, the network operating regime and other factors, using filters becomes not productive enough [2].

Except for the mentioned above drawbacks all microprocessor-based relays have, HSATS devices have common problems faced in operation irrespective of the manufacturing company. One of the serious problems faced during introduction of new technologies is lack of highly qualified personnel. In order to provide qualified HSATS maintenance it’s necessary to establish special training centers as it’s possible to learn such devices operation in practice only during pre-commissioning work that is strictly time-constrained. The next problem is the question of operation of HSATS devices covered by warranty. In case separate units or the whole device come out of action, or in case of the device misfunctioning, it’s necessary to solve the problem quickly; that becomes impossible as at the moment there are no HSATS manufacturing company experts at the plant. This problem is especially substantive among those who use HSATS devices that are situated very far from service centers when problemsolving requires not more than an hour and an expert need several days to arrive.

One more problem connected with HSATS devices is insufficient data support. Oil and gas industry plants use both modern HSATS of SUE3000 type or Bresler type, and old-fashioned devices of BPU (computerized numerical control system) BE (electronics module) 8302 type made at the end of the previous century. The engineering documentation of recently made HSATS devices describes in detail not only the operation principle of the whole device, but also that of its separate units with computations. The engineering documentation of modern HSATS devices gives only a brief description of the device behavior, but there is no data concerning separate units operation; that creates additional problems during post-warranty service.

Findings

So, it may be concluded that the introduction of HSATS devices to oil and gas industry plants power-supply systems can be possible only after thorough evaluation of the existing power supply diagram, network capacity determination in cases of emergency, analyses of economical efficiency in case of the device introduction, and the compete idea of all the difficulties arising during this device operation.

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