New approach to the implementation of the under frequency load shedding function in micro grid

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Abstract. In the presented study, a modern method has been developed related to the analysis of the network at 10 kV and 0.4 kV, using the methods of mathematical modeling it is possible to ensure the creation of the same network with different parameters. It can be seen from the work that the UFLS teams make it possible to ensure the stability of the functioning of the electric power system.

1. Introduction

The development of the electricity market today and especially in the long term requires a detailed consideration of the energy dependence of modern infrastructure, information systems and socially significant facilities during the implementation of emergency load shedding. For such disconnections are used the devices of special automation of load limitation (SALL) [1; 6], under frequency load shedding (UFLS) and dispatcher commands. When the load is disconnected at a level of 0.4 kV, all consumers are switched off, however, with selective disconnection of a load at a level of 0.4 kV, can be saved some important loads. When the load is disconnected at a level of 0.4 kV, all consumers are switched off, however, with selective disconnection of a load at a level of 0.4 kV, can be saved some important loads. In power systems, an emergency limitation during frequency reduction is implemented by the multi-element structure of software and hardware.

When the micro grid is switching to isolation mode the reliability of power supply of important consumers is provided by translating the load shedding function from the 10kV to 0.4 kV. The transition to the level of 0.4 kV is achieved through the integration of the Automated System for Commercial Accounting of Electric Power (ASCAEP) and the emergency automation devices, including for the implementation of UFLS commands [7].

The main purpose of the fast-action of UFLS's settings is to prevent a decrease in frequency below 46 Hz. and compliance of the conditions of selectivity, i.e. avoiding unnecessary load shedding with subsequent increasing frequency above 50 Hz. The UFLS-I is considered in this paper.

2. Materials and methods

The aim of this work is to study the approach to implementing the load disconnect function at a low frequency. The objectives of the study are as follows:
• Study management systems;
• Simulate the management process.

The study is based on the use of various scientific methods and technical approaches, which allowed forming a model of the control system.

3. Results
An example of the integration structure of the programming technical complex (PTC) of UFLS and ASCAEP shows in Fig 1. There is envisaged to maintain the current order of location of USLS devices on 10 kV feeders with an action to trip. When the frequency decreases, the command from the UFLS device is transmitted to the 10/0.4 kV network for disconnecting the load in the form of a dip of the supply voltage for a given duration (taking into account the scatter) by disconnecting the on/off switch of the 10 kV feeder's breaker. The management of each of the disabled 0.4 kV consumers is carried out by the contacts of individual electricity metering devices. In this case in many of the electricity counters will start a control algorithm for metering the duration of the dip voltage, subsequent activation after a specified time of the circuit breaker 10 kV generates a command to trip the network of 0.4 kV, which reacting many of the energy-accounting counters. After that, the most prioritized (important) part of the electric consumers will not switch off, which it is the purpose of this work.

The output circuit of the UFLS device is connected to the logical input of the microprocessor protection relay, which will turn off the breaker without delay (figure 1). This implementing a variant of the fast-acting load shedding by command of settings UFLS-I.

![Figure 1. The structure of integration of software-hardware complex of UFLS and ASCAEP’s systems.](image-url)
electricity metering devices with a control contact at consumers 0.4 kV. The UFLS devices currently installed remain with their position on the 10 kV level, and their tripping signals are transmitted to the 0.4 kV network using the switching cycle (on/off) of the 10 kV breaker. Signals for the implementation of control actions are distributed in the 0.4 kV network in the form of voltage dip with a pre-determined duration and are implemented in the algorithms of ASCAEP’s meters to turn off consumers. Accordingly, in the unified energy system will formed the unified management system [4-5].

Using the structure proposed in figure 1, it can be used for load shedding when occurs overload and turn it on again. The use of ASKAEP devices is considered effective. However, in case of power system trouble their operation is considered unreliable [5]. The impact of induction motors on the duration of voltage dip which uses as a signal was studied in [6; 8-11].

4. Discussion
The behavior of the power system’s frequency change under the action of the UFLS obtained by modeling in PSCAD software shows in figure 2 under the following conditions.

The maximum calculated deficiency of active power during the transition to the island mode is $\Delta P_{\text{def max}} = 50\%$, then the maximum amount of the load connected to the fast action UFLS-I settings is accepted $\Delta P_{\text{C}} = 55\%$ more 5%.

The inertial constant of rotating masses of power system $T_J = 5.0$ s, is the load-damping constant $k_{\text{reg}} = 2.0$. The number of settings is assumed to be 20 with frequency settings from 48.8 till 46.9 Hz. with a uniform step in frequency of 0.1 Hz and uniform distribution of disconnecting load. Each setting disconnects the load in the amount of 55/20 = 2.75%. The group of graphics is generated by one parameter of the delay time $\Delta t_{\text{UFLS}}$ to implement the frequency relay signal in each of the UFLS devices. In addition, an additional delay is usually provided for detuning from short-term trips of the frequency relay during switching in distribution networks. In a series of experiments, was used a set of 3 values $\Delta t_{\text{UFLS}} = 0.15, 0.2, 0.3$s. (figures 2, 3).

The mathematical model based on PSCAD set values of the above parameters micro grid was implemented the multi-interval exponential processes. In the initial operation at $t_0 = 0$ the time constant of the frequency change is:

$$\tau_{f_0} = \frac{T_J}{K_{\text{reg}}}$$  \hspace{1cm} (1)

where $k_{\text{reg}}$ is the load-damping constant. When a deficiency $\Delta P_{\text{def}}$ (%) occurs, the frequency as exponential with a time constant decreases to a new steady-state frequency value:

$$f_{\text{st.}} = 50 - \frac{\Delta P_{\text{def}} \cdot f_0}{100 \cdot k_{\text{reg}}},$$ \hspace{1cm} (2)

Under the action of the UFLS-I in the process of reducing of frequency, a multiple reassignment of all parameters of the transient process occurs, which leads to a steady-state frequency value taking into account the action of the N-settings of the UFLS-I in the expression:

$$f_{\text{st.}} = 50 - \frac{(\Delta P_{\text{def}} - \sum_{i=1}^{N} \Delta P_{1-i}) \cdot f_0}{(100 - \sum_{i=1}^{N} \Delta P_{1-i}) \cdot k_{\text{reg}}}$$  \hspace{1cm} (3)

where $\Delta P_{\text{def}}$ - volume of power deficiency; N-is the number of UFLS-I’s setting, $f_0$ is the nominal frequency value, and $\Delta P_{1-i}$ - the power of the i-th UFLS-I's setting.
Figure 2. Frequency changing behavior when the deficiency occurs in one step. Traditional -1 and new approach-2.

Figure 3. Frequency changing behavior when the deficiency occurs in two steps. Traditional -1 and new approach-2.

In figures 2 and 3 shows the oscillograms of Implemented model when operated the settings from 15 till 20 which formed as a set of 30-40 or more time intervals. The event (deficiency of power) will be occurs at 20 second of modeling process.

A series of graphics in figure 2 allows to visually evaluating the efficiency of the UFLS with various probable initial parameters. It is clearly seen that at $\Delta t_{UFLS}$ values of 0.3 s and occurs the effect of deregulation, that is, excessive load disconnections with a subsequent increasing the frequency above 50 Hz and the action of regulators of power plant units for reducing the power generation. This situation is not permissible and is characterized as non-selective and this non-selective action is occurs due to a delay during implementation of the UFLS's signals. Authors using the duration of voltage dip as a signal in the 0.4 kV network as a task to evaluate the impact of this voltage dip at functioning of the load shedding and prevent non-selective action UFLS-I. In figure 3 shows model oscillograms of a frequency change under the same conditions as in figure 2, but in cases event of a deficit in two steps.

In this context of the implementation of the transferring of the UFLS's signals to the level of 0.4 kV used of a voltage dip with 2.0 s duration as a signal to load shedding.

The value of non-disconnecting loads on each of feeder was accepted 20%. Consequently the amount of load which to be connected to each of UFLS's setting must be increased from the value of 2.75 till 3.44%.

During operation main of breaker the feeder of 10 kV without delay will disabled with a volume of load 3.44%, and after 2.0 s. will turns on with a load of 0.68%. In this case, the 2.75% of load is disconnected by the signals of numerous meters in the 0.4 kV network. The compared oscillograms it is clearly seen that in both cases the main purpose of the fast-action of UFLS-I subsystem is quite satisfactory, with almost identical minimum frequency values $f(t)_{min}=46.8$ Hz. engineering

In the unified energy system of the Republic of Tajikistan the minimum acceptable frequency value is 46 Hz and under the considered conditions this requirement with a reserve in both cases is performed. But the requirement of selectivity and preventing unnecessary load shedding is performed differently.

In the traditional case, the violation of the selectivity requirement at $\Delta t_{UFLS} = 0.3$ s, according to the conditions of figure 2.

Load disconnection at 0.4 kV level under action of UFLS signals in the form of dip voltage duration 2.0 s. radically will change the transition process due to short-term load shedding and after
that occurring switching on of load. Therefore, raising the frequency and the possibility of excessive non-selective load shedding on the oscillograms shows in figure 3 is not observed.

As is shown in figure 3 frequency hanging in the range of 48.5 ÷ 46 Hz. is limited in time (90-100) s. and it is eliminated by the UFLS-II settings combined with the UFLS-I settings at the same consumers. It is advisable to keep the implementation of the commands (signals) of the UFLS-II category as the settings of the UFLS-I with the transfer they implementation to the level of 0.4 kV.

In figure 4 shows the behavior of the frequency change when the deficiency is 50% and increase slowly during 4 minutes. The traditional and proposed methods as a whole demonstrate the spasmodic form of the frequency, moreover, both methods successfully prevent an "avalanche of frequency", however, they can allow an excess of the residence time duration of frequencies outside of the control area. To prevent this drawback should be in reasonable cases apply the under frequency load shedding device with time-variable setting in frequency [2; 12-14].

5. Conclusion
The simulation results clearly demonstrate the validity of the proposed method for implementing of load shedding signals to disconnection the power consumers of 0.4 kV. By the use of voltage dips as a signal to turn off power consumers the efficiency of load shedding is not reduced.

In some cases, the effectiveness of the proposed method with dip voltage can be increased by eliminating unnecessary load shedding in maximum deficits mode. This property will increase in the future as the influence of the inertia of the rotating parts of the power system decreases by using renewable energy sources which operating with invertors.

At subsequent stages of the research it is advisable to move the pilot project and to equip a feeder for the 10 kV devices for transmission signal to load shedding in the 0.4 kV network.

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