Аналогичные изменения получаются при обрыве одной из фаз генератора. В случае обрыва двух фаз или короткого замыкания между фазами емкостей самовозбуждения асинхронный генератор теряет возбуждение.

Таким образом опытные исследования позволили выявить характер изменения величин токов и напряжений автономного асинхронного генератора при обрыве одной из фаз генератора, а также полном или частичном обрыве фаз емкостей возбуждения. Данные информационные признаки необходимы для разработки соответствующих устройств защиты, в качестве которых можно, например, использовать устройство, реагирующее на изменение вибрации корпуса генератора при повреждении [1]. Так как с помощью сигнала вибродатчика имеется возможность обнаружения не только электрических, но и механических повреждений, поэтому его целесообразно использовать для построения устройства защиты генератора.

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Kondrateva N.P., Shishov A.A., Bolshin R.G., Krasnolutsкая M.G.
Digital technologies for monitoring and implementation of smart diagnostics of the
isolation of power supply systems with isolated neutral in the operating mode

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Abstract

Nowadays, 75% of emergencies at power supply facilities are caused by single-phase ground faults. The currently used methods of thermal imaging and ultrasonic testing do not allow accurately identify the cause of accidents in electric power distribution systems. The current search generators, due to their low power, cannot cover the entire section of the diagnosed network. The article suggests the use of digital technologies for the intelligent diagnostics of the insulation of power supply system with insulated neutral in the operating mode, allowing on-line diagnostics of the network and analyzing the data obtained for the early prevention of emergency situations. In order to avoid disconnecting sections and diagnose the system in operating mode, it is proposed to check the system using a current-limiting capacitor, which will be connected to the live parts of each phase under voltage and accurately determine the location of a single-phase short circuit for any number of feeders. The relevance of these studies is due to the fact that, for example, during two years at one of the manufactures 19 emergencies related to single-phase ground faults were recorded. Four of these cases led to a complete stop of the production. Therefore, the development of digital technologies for the implementation of smart diagnostics of the insulation of an energized power supply system with insulated neutral will be of interest to practitioners, scientists, researchers, graduate students and other specialists seeking to study the latest achievements in smart agribusiness for their subsequent application in the real world.

Keywords: insulated neutral system 6, 10 and 35 kV, insulation fault locations, hidden insulation faults, single-phase ground faults, WEB AI, ERP, digital control.

Аннотация

В настоящее время 75% аварий на объектах электроснабжения вызваны однофазными замыканиями на землю. Применяемые методы тепловизионного и ультразвукового контроля не позволяют точно определить причину аварий. Современные поисковые генераторы маломощны и поэтому не могут промониторить весь участок диагностируемой сети. В статье предлагается использование цифровых технологий для smart диагностики изоляции системы электроснабжения с изолированной нейтралью в рабочем режиме, позволяющих проводить оперативную диагностику сети и анализировать полученные данные для раннего предупреждения аварийных ситуаций. Во избежание отключения секций и диагностики системы в рабочем режиме предлагается проверить систему с помощью токоограничивающего конденсатора, который будет подключаться к токоведущим частям каждой фазы, находящейся под напряжением, и точно определять местоположение одиночного короткое замыкание фазы на любое количество фидеров. Актуальность этих исследований связана с тем, что, например, за два года на одном предприятии было зарегистрировано 19 аварий, связанных с однофазными замыканиями на землю. Четыре из этих случаев привели к полной остановке производства. Поэтому разработка цифровых технологий для реализации интеллектуальной диагностики изоляции энергосистемы с изолированной нейтралью является актуальной задачей и будет интересна практикам, ученым, исследователям, аспирантам и другим специалистам, стремящимся изучить последние достижения интеллектуального агробизнеса. для их последующего применения в реальном мире.

Ключевые слова: система с изолированной нейтралью 6, 10 и 35 кВ, места повреждения изоляции, скрытые повреждения изоляции, однофазные замыкания на землю, WEB AI, ERP, цифровое управление.

Introduction

To date, there is no method in electric power distribution for diagnostics of insulation of branched power supply networks under voltage. Due to insulation failure, capacitive currents arise. Capacitive single-phase ground fault currents lead to activation of protection with subsequent shutdown of the damaged section of the circuit. Further search for such damage is difficult [1, 2, 3]. The currently used methods of thermal imaging and ultrasonic testing do not allow to accurately identify the cause of accidents in distribution networks [4, 5, 6]. The current search generators, due to their low power, cannot cover the entire section of the diagnosed circuit [7, 8, 9]. A phase-to-ground fault is abnormal and dangerous for a number of reasons:

1. There is a danger of electric shock to service personnel and consumers;
2. With a long-term presence of a single-phase ground fault in the network, accelerated aging of insulation and damage to electrical equipment occurs;
3. Ferroresonance phenomena are possible (especially with alternate disconnection of power consumers), from which voltage transformers most often fail. [1]

Materials and methods

When calculating single-phase ground fault currents, a method based on the determination of the capacitive ground fault current is used. The values of the specific capacitive ground fault current can be found in the reference books or taken from the technical characteristics of the equipment provided by the manufacturer.

The reference books do not contain data on the capacitive currents of overhead lines, generators and busbar systems. Therefore, to determine the total capacity of the entire electrical installation, it is necessary to make a calculation. The calculation of the specific capacitive current using the capacitance relative to the ground is carried out according to the formula (1)

$$I_C = 3 \cdot U_F \cdot \omega \cdot C_o \cdot 10^{-3} \quad (1)$$

where:

$$U_F = \frac{U_L}{\sqrt{3}} \quad \text{- Phase-to-neutral voltage (kV)}$$

$$\omega = 2\pi f = 314 \quad \text{- Angular frequency (rad/s)}$$

$$C_o \quad \text{- Phase-to-ground capacitance (μF/km)}$$

The calculated values are used to set the relay protection settings for localizing the damaged area. But the search for the location of the damage itself is carried out by personnel. In order to avoid disconnecting the sections and diagnose the network in the operating mode, it is proposed to check the system using a current-limiting capacitor, which will be connected in phases to live parts under voltage. Thus, there will be a change in the phase capacitance C_o relative to ground, as well as a zero shift, which will lead to an increase in the phase voltage to a linear value. The phase voltage will increase from $U_F = 3,7 \text{ kV}$ to values close to linear $U_F \approx 6,3 \text{ kV}$. This mode can be considered as high-voltage tests of equipment, which, according to regulatory documents for insulating equipment, are carried out only before installation into operation. If during the tests there is a loss of the insulating properties of the diagnosed object, the current modulator, which is connected in series with the current-limiting resistor, will be able to localize the place of the network fault. The method described above will allow:

- Accurate determination of a single-phase ground fault location for any number of feeders and their relative position in the vicinity of the switchgear.
- The search current does not spread over all outgoing feeders of the electrical installation, but flows directly through the place of the formed damage.
- The created search current allows diagnosing the electrical installation and detecting a malfunction in the stage of its formation.
- Allows to find cases of occurrence of a self-healing fault, a single-phase ground fault, which, with changing weather conditions, restores its insulating properties.

Conclusion

The obtained data can be integrated into a single ecosystem of smart substations using the example of a “smart home”[3,4]. Each large power supply facility, as a rule, has its own OPS server, which collects and outputs data to the client's SCADA system. The measurement results after checking the insulation using the protocol RS-485 (mudbus) or Ethernet (60870-104) can be collected in the local AWS system and transmitted via LTE | MQTT | HTTPS to a single WEB AI center, which in turn, according to the algorithm AI will monitor and analyze the power system. Data will be collected from hundreds of substations and thousands of consumer feeders integrated into a single system.

The described technological processes cover only the lower steps of the automation pyramid and are limited to the level of Automated Process Control System (APCS) and Control & Instrumentation (CI). However, thanks to the collected and processed data from WEB AI, it is possible to establish and organize interaction with higher levels of the ERP system.

To date, the problem solved during the implementation of the project is significant not only for “smart” agriculture [6, 7], but also for industry. In 2018-2019, 19 emergencies related to single-phase ground faults were registered at one of the gas production facility. Four of these cases led to a complete shutdown of the production. The existing methods of detection and localization of damage sites are problematic and take a lot of time, since the inability to diagnose these damages in advance affects [8]. The introduction of the proposed method into the production process will reduce the time and minimize losses. The tests of the proposed method for determining the locations of insulation damage were carried out at the “Pligon”

substation in the city of Votkinsk. In all cases, the damaged area was localized. Thus, the development of digital technologies for the implementation of smart diagnostics of the isolation of an energized power supply system with isolated neutral is relevant and will be of interest to practitioners, scientists, researchers, graduate students and other specialists seeking to study the latest achievements in smart agribusiness for their subsequent application in the real world.

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