Application 13

Protection by Automatic Disconnection of the Faulty Area

1. Protection against electrocution

Technical Standards for security distinguish two categories of electrocution. They are produced by:

- **direct contact** of the conductive elements which:
  - are supplied from a network;
  - were disconnected from voltage, but: remained loaded with capacitive load or on which may occur electromagnetic induced voltages.
- **indirect contact**, this means the touch of the conductive elements, which are not normally under voltage, but can come into contact for elements that are under voltage as a result of a fault in the insulation.

Electrical safety for direct contact requires the following measures with elements that are on voltage:

- marking them by visible inscriptions and / or color (usually yellow or orange);
- their protection by insulation (for example, terminals or devices);
- their protection by switching off (in case of an opened panel, that are introduced in boxes or special rooms);
- use of apparatus with protection degree increased in installations or special rooms for unqualified personnel;
- organizational measures for conditional access in installations or systems with increased danger;
- use of individual protection;
- warning systems and / or automatic disconnection in case that persons access the danger zone (usually the acoustic warning is done with a buzzer, bells, horns), etc.

Electrical safety for indirect contact is based on three categories of measures on the protected metal parts:

- coupling at the null protection or neutral connection;
- grounding to the earth plate (except luminaires)
- use on choice of one of the additional protective measures, including the following: use low voltages obtained by the galvanic separation from the power supply/ main grid; additional insulation protection; equipotential bonding metal parts that can be achieved simultaneously; automatic disconnection of faulty sector.

Depending on the degree of danger are used in the given order, one, two, or al three categories.

2. Connection at the null protection or to earth plate

Conductive elements, usually metal housings, of the electrical equipment are connected to neutral (which is different from the null) or ground earth plate.

These installations are intended for receivers protection, equipment, switchboards, etc. whose power comes from the transformer connected to a secondary neutral grounding. Under certain conditions, grounding can be used as the primary means of protection and also in the case of isolated neutral ground networks.

These protections benefit from the existence of short-circuit protection devices (fuses, relays, electromagnetic or triggers) and sometimes the presence of overload protection devices (thermal relay receivers or outlets from which they are supplied).

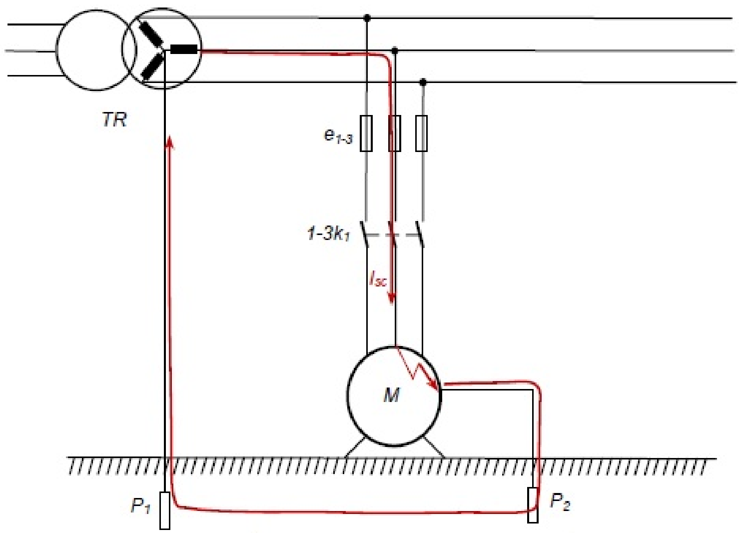

Fig 13.1 Ground earth plate

The step down transformer from the substation usually has the secondary in star connection with neutral connected to ground earth plate P1, as shown in Figure 13.1. Coupling the receiver housing or machine M to ground earth plate P2, the direct contact between the housing and an energized current path determine a flow of a short-circuit current produced by the phase voltage source. This current circuit closes after the next circuit: the given phase - short-circuit protection apparatus - faulty electrical connection connected to the housing - ground earth plate P2 - P1 ground earth plate - neutral grid.

The short-circuit current protection device determines the operation on that stage. Receiver housing will be removed from the power supply and the danger will be removed.

This system is used for both receivers or equipment with metal casing elements for both the three-phase power, and those with single-phase power, where there is a danger of accidents by indirect contact.

The system has the following disadvantages:

- insulation grounding or circuit interruption outlet increases the danger of electric shock;
- increase grounding resistance or unsatisfactory contact on the current path can cause low short-circuit currents, which would not trigger the protective apparatus, but unnecessarily increases the specific consumption of electricity and heat insulation, possibly followed by major faults and even fires;
- the system does not work in case of induced voltages.

These disadvantages have led to the application of additional protection measures mentioned above.

3. Supplementary protection systems

The supplementary protection systems are:

- protective separation;
- supplementary protective insulation;
- low voltage supply;
- equalization of the potentials;
- protection by disconnecting the faulty sector.

3.1 Protective separation

The receiver is powered by a separate transformer or a motor-generator. If the environment presents high humidity or conductive particles deposited or suspense, the supply voltage of the receivers is below 50V.

The secondary winding separation transformer will be isolated from the ground. Both the primary and secondary side are provided with fuses.

3.2 Supplementary protective insulation

Supplementary protective insulation is applied:

- for equipments, and consists of insulating material covering the elements that could become active in the event of a fault, respectively in strengthening insulation on live elements that are likely to be reached;
- on the workplace, and consists in insulating metallic elements contained in handling area (delimited to a radius of 1.25 m around the workplace).

3.3 Equalization of the potentials

The equalization of the potentials is used in workspaces where the appearance of potential difference is possible between the housing of the grounded equipment. It is achieved by the direct electrical connections between metal objects that can be reached simultaneously.

3.4 Protection by disconnecting the faulty sector

This supplementary protection system involves the detection systems (to detect the fault) and command interruption in the power supply fault. Being more complicated systems and devices including mobile contacts, there are less reliable and more expensive than the previous.

Even if their correct operation doesn't need surveillance, the system must be tested periodically. Consequently, the systems are equipped with control devices that involve other mobile contacts. When designing control device consider not to create a dangerous situation for service personnel. Consequently, at least the connection to the protected object can not be directly controlled in this way.

From the disadvantages mentioned, they should not be used unless the previous methods are not satisfactory in areas where danger is high or if the protected equipment are high value.

4. Installations for automatic disconnection of faulty sector

Using this type of protection is constantly expanding. These installations are used as a backup system for protecting plants by grounding or protective ground.

After destination, the automatic protection systems divide into:

- automatic protection operating at the appearance of dangerous voltages (PATA);
- automatic protection operating at the appearance of dangerous fault currents (PACD);

The installations from the first category acts directly against the danger of electric shock by indirect contact.

The second category acts directly against the dangers of destroying the machine or the receiver, generating fire, and against unnecessary increase in specific consumption of electricity. It also acts indirectly against shock hazard and prevent electrocution through indirect contact with the pace voltage

4.1 Automatic protection operating at the appearance of dangerous voltages (PATA)

PATA protection is to detect the occurrence of a dangerous voltage on the metal elements that are not part of the electrical circuit and command the disconnection of the defected equipment. This must be done in a maximum of 0.2 seconds.

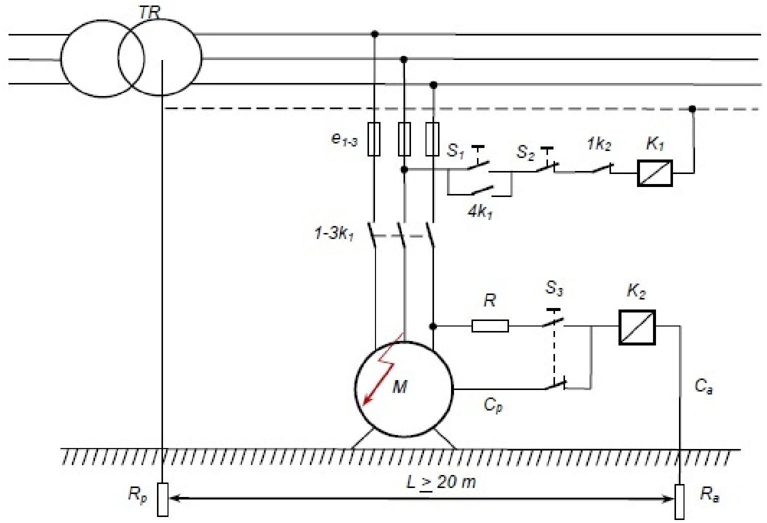

Fig 13.2 Automatic protection operating at the appearance of dangerous voltages

PATA protection occurs when the protected equipment is grounded, or the connection was deteriorated.

The basic electrical scheme is shown in Figure 13.2. The protective installation consists of: K_1 connection / disconnection of the receiver or machine M, protective relay K_2, the controller S_3 proper functioning of protection, all of which are often mounted in the same enclosure. The system includes: Auxiliary ground Ra, located in an area of potential null conductor. As for coupling K_2 relay coil outlet and wire coils C_p for coupling to the same machine housing. So K_2 protective relay coil is mounted inside the machine housing and auxiliary outlet R_a, acting on voltage fault occurrence (or contact).

At the appearance of a dangerous voltage on the M machine housing in relation to its grounding plug R_a, K_2 relay will operate. Protection works only grounded neutral networks, the K_2 coil circuit can be closed. At the switching of relay K_2, normally-closed contact opens interrupting $1K_2$ K_1 contactor coil circuit. Its main contacts - 1..3 k_1 - will open, disconnecting the machine on which appeared a dangerous voltage.

The relay K_2 must disconnect the faulty voltage at no more then 24 V auxiliary socket if the resistance of the earth ground is 200Ω. Generally the triggering occurs when the tensions are low (fig.13.3).

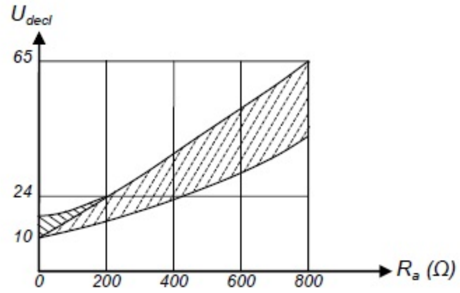

Fig.13.3 The tripping domain of the protective relay depending on the resistance auxiliary socket

In figure 13.4 is indicated the voltage vector diagram of the switch on of the protection relay mounted in a network with grounded neutral.

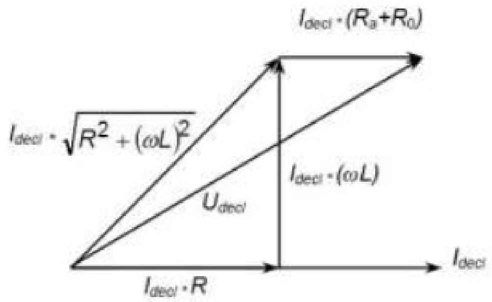

Fig.13.4 Vector diagram for triggering voltage protection relay

Therefore:

$$U_{decl} = I_{decl}\sqrt{(R+R_a+R_0)^2+(\omega\cdot L)^2}$$

, where:

R - protective relay coil resistance, [Ω]

R_0 - the neutral grounding resistor network, [Ω]

Ra - auxiliary grounding resistance K_2, [Ω]

ωL - reactance relay coil, [Ω],

I_{decl} – triggering current, [A], whose value is between 12÷60 mA (generally,

I_{decl} = 40mA).

But $R_0 << R + R_a$, so the trigger voltage can be written:

$$U_{decl} = I_{decl}\sqrt{(R+R_a)^2+(\omega L)^2}$$

[V] . Generally, U_{decl} =10÷24 V.

The total opening of the normally-closed contact (during its opening time plus the electric arc time) depends on the protective relay voltage fault. Thus, if the voltage is less than 30V, the onset is later than 0.5 seconds; to a value greater than or equal to 30V triggering is done in less than 0.2 seconds. Relays that can be used for protection against touch voltages must trigger time under 0.1 seconds, so it can be considered to act instantly, which is a key advantage of this type of protection.

The control device S_3 is composed of a double-contact push-button and a limiting resistance R. This device is used to periodically tested to the system. By pressing the fault is simulated by binding phase in the relay coil K_2, current limiting resistor R simulation. By the second contact of switch S_3 is taken and measure voltage protection fault occurrence (sample) on the machine housing. If the system protection is in good condition, they reset. In this way are checked: $1K_2$ contact relay coil of contactor K_1, auxiliary grounding conductor of relay K_2 and auxiliary outlet. It is recommended a check once a month.

Regarding thr performance of the protection system, auxiliary ground electrode should be placed in an area of ground potential. Otherwise it bypasses the relay coil protection. It is generally sufficient for auxiliary outlet to be installed at 20m from the outlet to which they are related equipment housings. It is recommended that the resistance of the auxiliary socket should not exceed 200Ω . Only in exceptional cases, for example in rocky or sandy ground a 800Ω is allowed, but triggering occurs at a voltage of 65V fault (Fig. 13.3).

4.2 Automatic protection in case of dangerous fault currents (PACD)

This type of protection occurs when a route-phase-ground housing there is a current higher then the value of the load current and lower then the trigger current of the maximal protection.

The main advantages of this protection are:

- avoids maintaining voltages on metallic elements that are not part of the current working circuit and having too much resistance in their connection with the ground electrode: $R_p \geq \frac{U_{a.ad}}{I_d}$, where $U_{a.ad}$ is the permissible touch voltage and I_d is the fault current;
- avoid accidents caused by direct contact, if a trigger sensitivity enables faster protection than 0.2 seconds when splitting a maximum touch current of 30 mA;
- eliminates the consumption of electricity produced by the fault current;
- sometimes allow more rapid detection of the fault;
- prevents the expansion of the defect due to rapid disconnection of reduced fault currents;
- protects an equipment (receiver) or a specific area.

The principles underlying the design of PACD schemes are:

- detecting an additional current;
- detecting an imbalance in supplied protected equipment.

4.2.1 Detection of additional current

It can be measured any currents appearing or whose value changes as due to the defect. Therefore we distinguish the solutions:

- fault current detection;
- detecting a operative current;

4.2.1.1 Fault current detection

These schemes are used in insulated neutral networks to ground and neutral movement and are based on three-phase power system if a failure occurs. Between the neutral line of the mains and ground current relay in series which can be connected directly or through a current transformer.

As the low voltage networks are usually neutral grounded to use this protection in this situation it is necessary that the power receivers or protected equipment to achieve through a transformer TR (Figure 13.5) transformation ratio 1: 1 and the secondary connected in star. Fault current detection is performed by current relay K_2 serially connected to the neutral grounding transformer secondary supply TR. The protected area can be reduced by introducing another transformer between its entry.

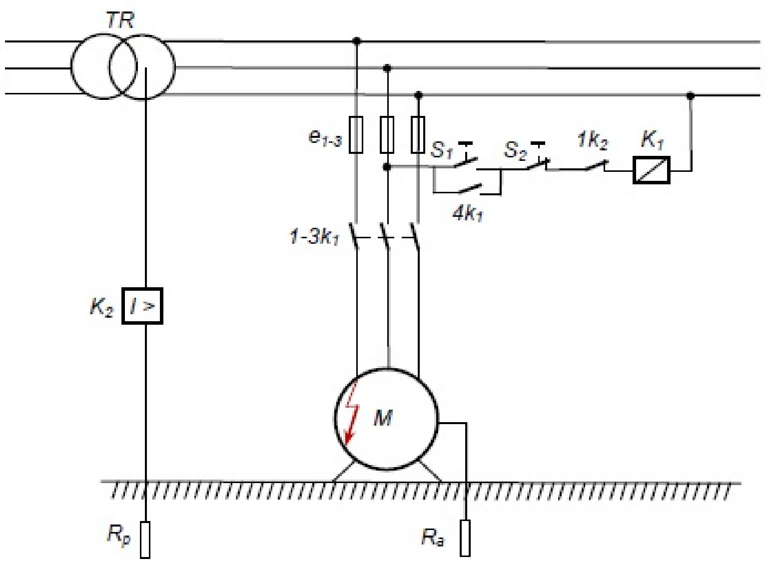

Fig.13.5 Fault current detection PACD scheme

The shortcomings of this solution, which limited its use in practice:

▪ protection acts according to the ratio of the insulation resistance of the phases and not by their absolute values (therefore if the decreasing of the insulation resistance is balanced or a three-phase short circuits occurs at the grounded housing, the relay doesn't detect a fault current);

▪ is not selective as it does not locate the fault, breaking off all receivers in the area;

▪ the solution can be applied also to isolate neutral networks, only if an artificial neutral is achieved (figure 13.6) and reactance X_{f1}, X_{f2} and X_{f3}, which entails other drawbacks, namely:

- makes worse the insulation network from the ground, as impedance elements constituting artificial neutral or impedance elements are connected artificial neutral and ground can not be sufficient;
- the size detected current depends on the value and mode phase imbalance of the phase network capacity in relation to the ground;

housing-ground voltage depends on the ratio ground-housing impedance or artificial neutral-ground.

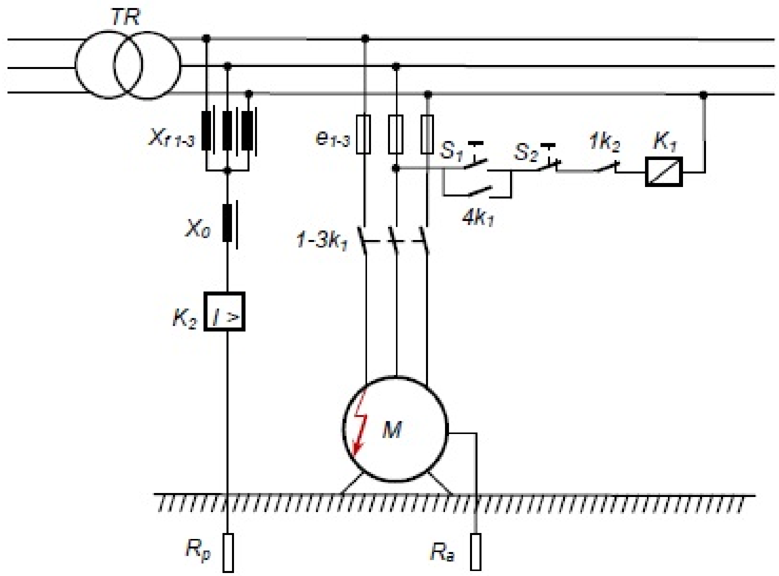

Fig. 13.6 Fault current detection PACD scheme, the development of artificial neutral

The artificial neutral is achieved, usually, with equal inductance to limit active power losses (Joule-Lenz effect). In contrast to the previous scheme, the protection works on the basis of the absolute values of the insulation resistance of the phases.

There is also the possibility of artificial neutral with three voltmeters (signaling scheme without relay). In this case, the occurrence of a fault on the path artificiall current housing-ground-null, voltmeter on the damaged phase indicates a lower voltage, in the range 0 - U_f and the rest voltmeters indicate a voltage in the range U_f -

√3 U_f. Obviously, in this case, the defect detection is dependent on the quality of the operator observation.

The disadvantages of this scheme are:

- the using only in well-isolated neutral networks from the ground, but with access to the null; for the using in networks with grounded neutral are required separation transformers;
- resistance of protective relay K_2 must be high, in order to decouple the small fault current ($I_d \leq 30mA$) and touch voltage under 40V.

As a result, the actual use of these schemes is limited.

4.2.1.2 Detecting an operative current

The protection scheme which uses an operative current (Figure 13.7) based on the previous scheme with artificial neutral, and used all networks with isolated neutral.

This protection is basically the application between artificial neutral and ground of a continuous voltage source, called the operative voltage source (STO), which greatly increases the sensitivity of the protection. The current is determined by the circuit under fault current and is called operative current.

In the absence of insulation fault, the operative current is null, because three phases are completely isolated from the ground. When insulation resistance falls below the permissible limit, the operative current increases and K2 relay clicks. A contact of relay K2 controls the opening of the K1 contacts of a switch or contactor line, so disconnection of faulty insulation zone.

The advantage of the scheme is that it can control both the relative values and the absolute insulation resistance.

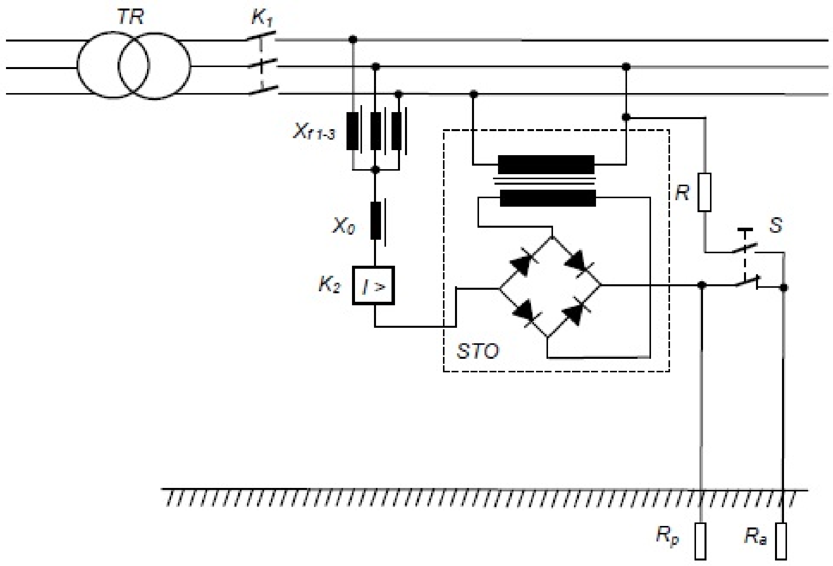

Fig. 13.7 PACD operative current scheme