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MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

Power stations - Electrical Part of Power Plants

(Electrical equipment of power plants)

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Literature: Prof. Ing. Zbyněk Ibler, DrSc., Doc. Ing. Miloš Beran, CSc.-Elektrárny 2, VŠSE 1982
Doc. Ing. Miloš Beran, CSc.-Electrical Equipment of Thermal Power Plants, VŠSE 1988

1. Division and operation of electricity generating plants (power stations)

According to the type of technology: conventional thermal power plants (fossil fuel power plants), nuclear power plants (NPP), hydroelectric power plants (storage, flow-through, pumped storage), wind power plants, solar power plants, ...

According to the focus of production: power plants (condensing power plants), heating plants (cogeneration units)

By arrangement: block units, interconnected technology

Thermal power plants by turbine type: condensing, back pressure, tapping

NPP according to the number of circuits: single, double and triple circuits

The production must ensure the necessary supply of electricity with the appropriate quality determined by the size and stability of the parameters:

- Frequency
- voltage magnitude level
- proportion of higher harmonic voltages
- voltage unbalance ratio

Maximum reliability and cost-effectiveness requires coordination of generation and trade of electricity against consumption based on load diagrams using:

- construction and operation of pumped storage power units
- Contractual regulation of the consumption diagram of wholesale customers
- strengthening of shift industrial operation and night tariffs
- use of the mass remote control system (HDO) for appliances
- the use of international cooperation in electricity interconnections

2. Electrical diagrams of power plants

The wiring diagram determines the topology of the wiring. The power supply system determines the power distribution system and ensures the supply of own consumption (hereinafter referred to as V.S.) with sufficient operability, reliability, safety and economy.

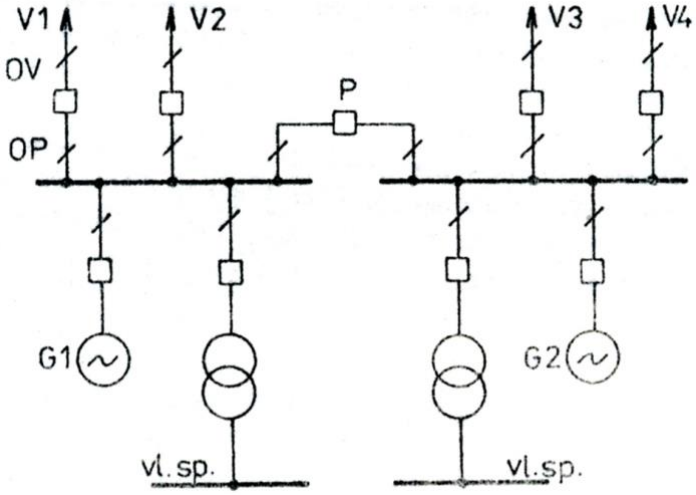
There are three level of customers where power loss will cause:

1. Threat to life, equipment crash or major economic damage
2. Significant reduction in production
3. Only partial limitation of production

Level 1 and 2 consumers must be supplied from at least two independent sources.

Topology of schemes:

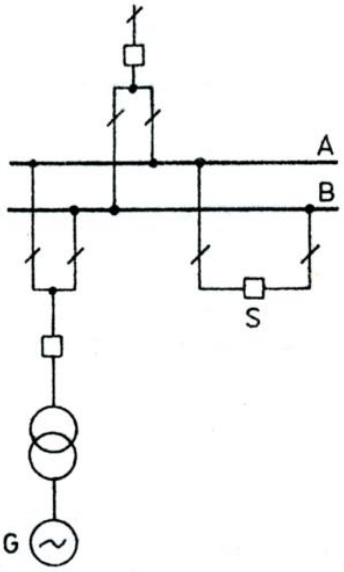
Simple busbar system



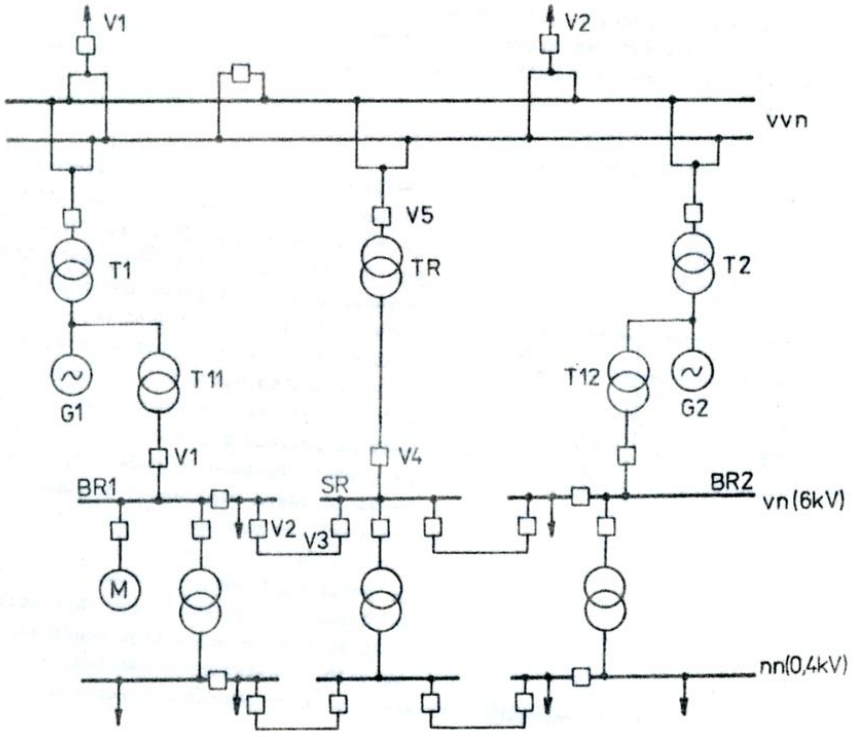
Each switch has an OP busbar disconnector and an OV pin disconnector

A longitudinal switch is required to separate the busbar section, busbar disconnector or circuit breaker in fault from the other block and for separate parallel operation reducing short circuit conditions.

Double busbar system:



Double busbar system and separate block and common V.S.:



Further improvements are possible with a three-busbar system or an auxiliary busbar.

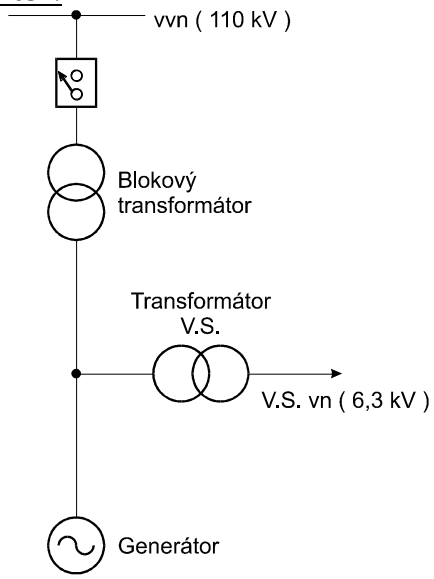
The requirements for the main electrical diagrams of the power plants are the assurance required:

- reliability and safety (according to consumer importance levels 1 to 3)
- operability (to allow for all varieties of operation including emergency production states, revisions and repairs)
- cost-effectiveness (investment and operational)

Depending on the number of blocks, 1 - 2 starting transformers are installed, or a new block transformer takes over the normal starting function.

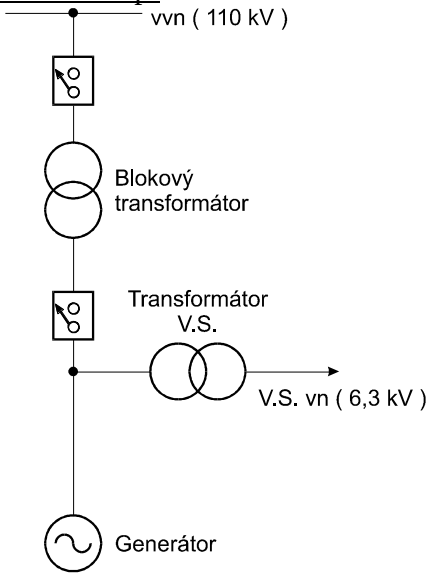
Block diagram alternator - block transformer - V.S. transformer

Diagram without alternator switch:



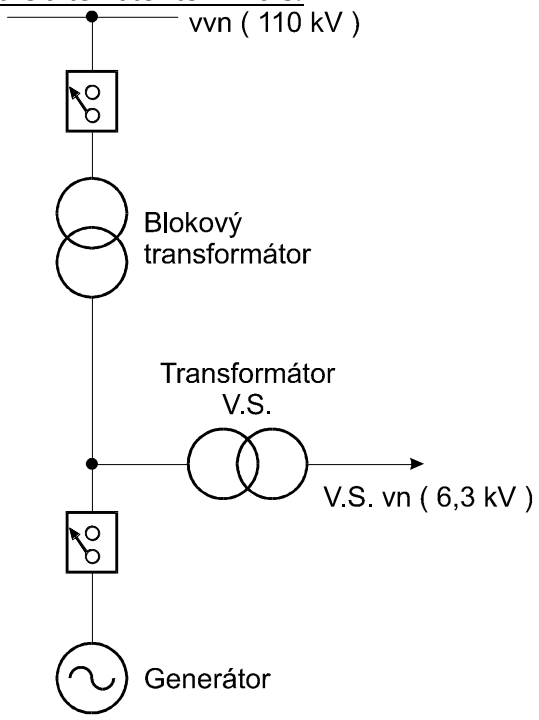
Required run-on transformer for both run-on and fault conditions. Cheap and clear scheme suitable for smaller units of several tens of MW.

With alternator switch behind the V.S. tap:



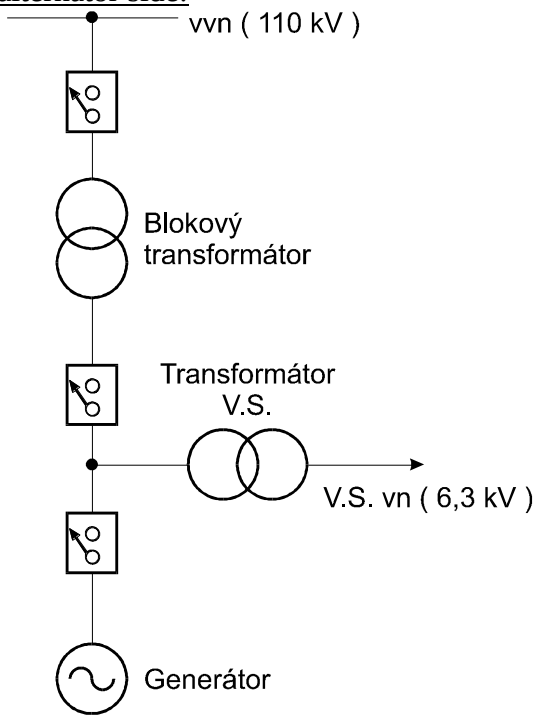
Again, a run-on transformer is required for both run-on and fault conditions. The advantage is continuous operation of the V.S. and alternator even in case of a fault on the block transformer, which is good for increasing the stability of the alternator even for cases of operation with reduced power only to the V.S. It is used in NPPs.

With alternator switch on the alternator terminals:



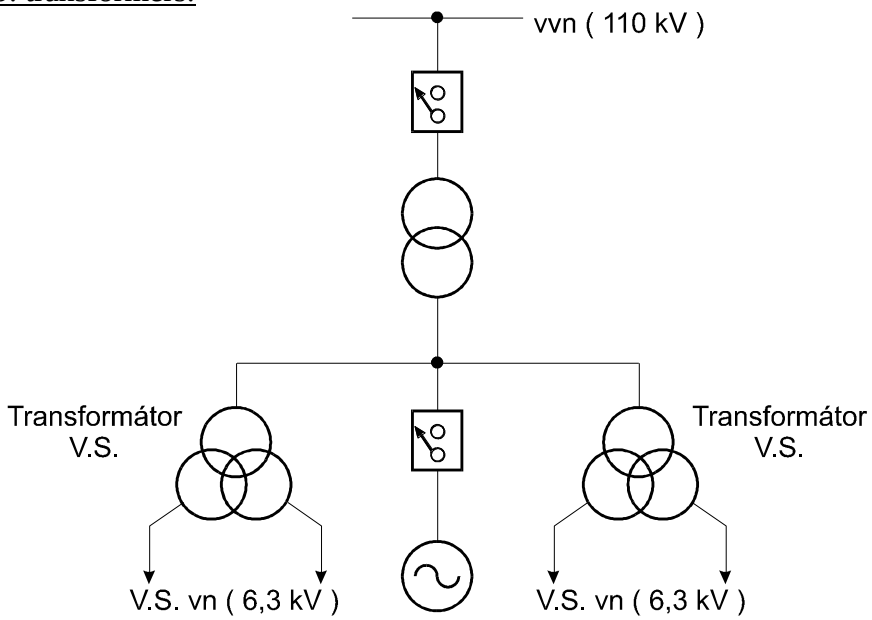
The block transformer is also used for block run-up, yet there is a spare run-up transformer for multiple blocks. It is used for large blocks.

With two switches on the alternator side:



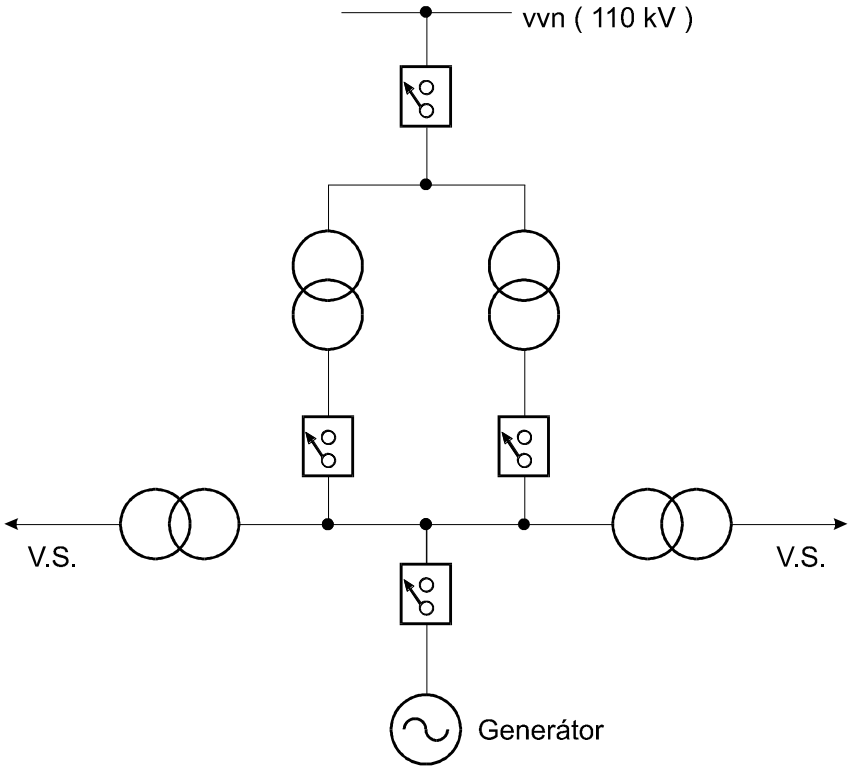
Combines the advantages of block transformer ramping and fault clearing

With two V.S. transformers:

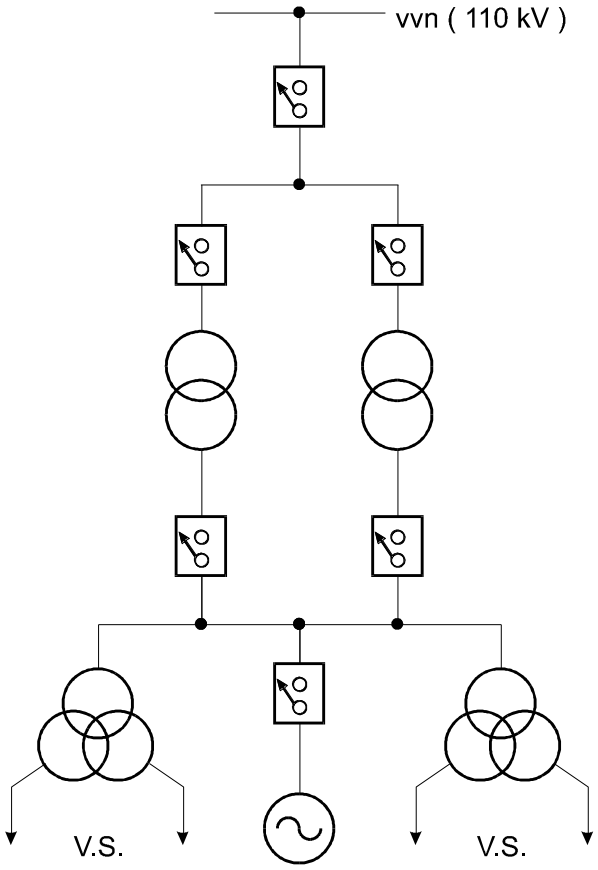


Use in NPPs with a capacity of over 400 MW.

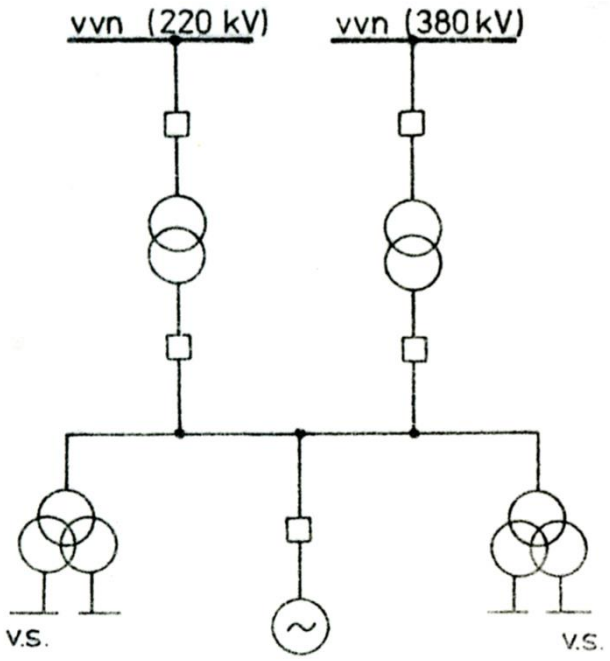
With two block transformers and V.S. transformers:



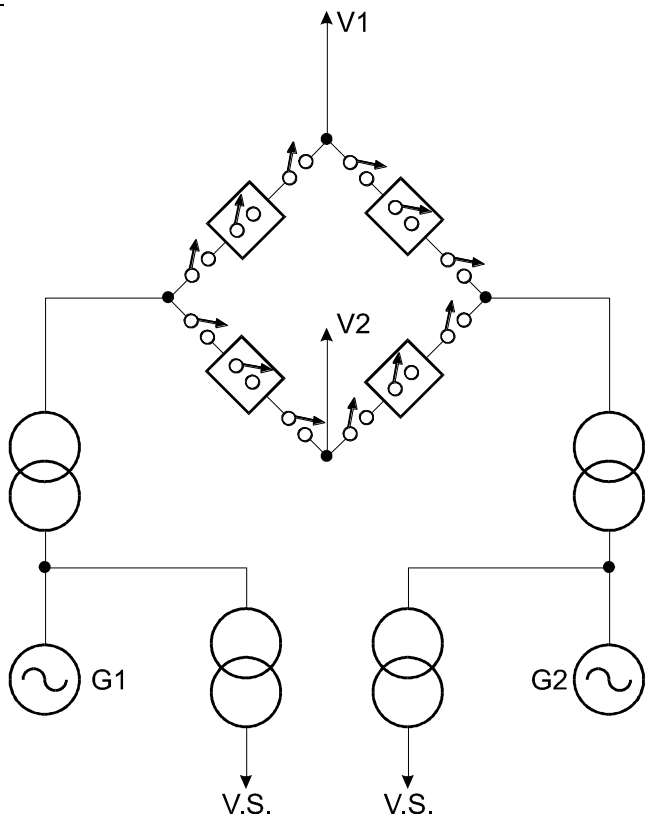
With two block transformers and V.S. transformers without the necessary emergency transformer:



Schematic for two different voltage systems vvn

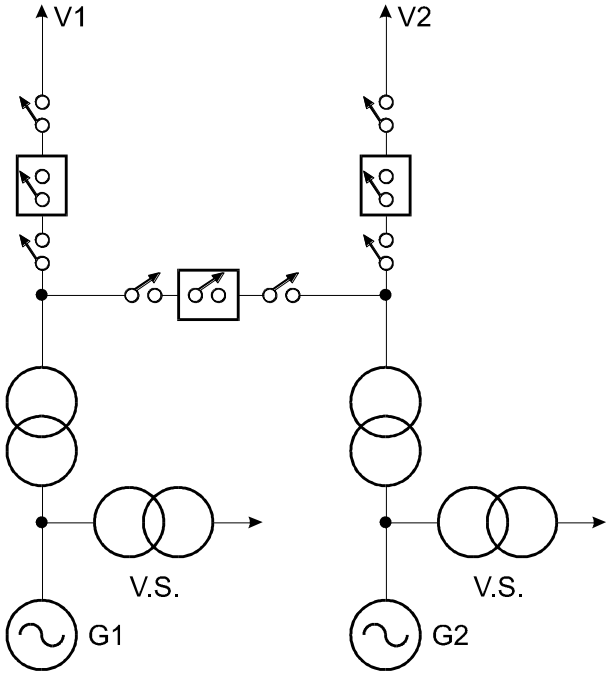


Quadrilateral scheme:



Despite its simplicity, it allows the transition of alternators between pins. The disadvantage is less clarity.

Scheme "H"



Simplification of the previous scheme suitable for space-limited solutions for hydroelectric power plants or distribution substations.

3. Own consumption (V.S.) of electricity of power plants

The V.S. electricity is the production consumption of the main and all auxiliary operations, including losses outside non-production appliances:

- Transport and fuel treatment
- Feed and cooling water pumping and treatment
- Flue gas desulphurisation
- Air and flue gas ventilation

Share V.S.:

- Coal-fired thermal power plants -7 to 11 %
  (if the feeder is driven by a steam turbine - 4 to 6 %)
- Thermal power plants using gas, fuel oil -5 to 6 %
  (if the power plant is driven by a steam turbine - 2.5 to 3.5 %)
- Heating Plants - 14 to 18 %
- Nuclear power plants -6 to 7%
- Hydroelectric power plants -up to 1 %

V.S. volume affects:

- Unit power of block machines and power units
- Quality and availability of the fuel used
- Power plant usage in the load diagram and the nature of its deployment
- Technical level (especially efficiency) of drives

The V.S. must be secured both during operation and during start-up and finally during shutdown of the power unit. During the run-up, it is important to provide power to equipment that would compromise the reliability of the plant, in particular:

- Nuclear reactor aftercooling at NPP
- Turbomachinery bearing oil pumps
- Control servo-mechanisms of turbo machines
- Measurement, control and protection systems

The technical provision of V.S. has historically evolved from separate turbo units at the main equipment, through dedicated alternators and electric drives, alternators on a common shaft of the main unit (still used today at hydroelectric power plants - e.g. Slapy, or partially at NPP - e.g. Jaslovské Bohunice) to the solution by a tap from the alternator outlet with the addition of a secured power supply through a special transformer from an independent source.

In addition, NPPs need to ensure increased safety and reliability plus a minimum frequency of reactor shutdowns. This requires dividing the appliances in the V.S. into groups of assured power supply according to importance, strengthening the quality of cabling, grommets, etc. Three completely independent power supply systems sufficient for all operating conditions and design failures, i.e. power supply systems, must be provided for each unit:

- Working
- Backup
- Secured by

In addition, the NPP has a fourth system of assured power supply for critical circuits and computing. Another specific feature of the NPP V.S. is the minimum common V.S., since most appliances are block-oriented. The systems must have self-switching latching. The V.S. is divided into independent sections for each generating unit.

The division of appliances into groups:

1. Appliances that allow short-term interruption of power supply or voltage drop for a maximum of 1 sec. (primary circuit circulation pumps, reactor control and protection, oil pump drives of turbo machines).
   The drives are divided into three stages:
   I. Loss of power supply causes danger to persons or equipment breakdown, or production shutdown of several units (boiler feed pumps, circulating cooling pumps) (according to the standard, up to 50 MW of unit output, the power supply is provided by a station battery, for larger units by a diesel generator, or a combination thereof). The contactors in this stage either do not trip or have to be switched back on automatically.
   II. Loss of power causes the unit to be disabled or reduced in production. These drives are equipped with undervoltage protection. Restarting is with a certain operating delay.
   III. Loss of power does not affect the size of production. These drives are equipped with fast zero shutdown. Restarting is automatic with delay or manual.
2. Appliances that allow short-term power interruptions or voltage drops of up to 3 minutes (emergency power pumps, intercooler pumps, boric acid pumps, supplementary ventilation)
3. Appliances with smaller requirements.

It is necessary to take into account the overload of the V.S. transformer during the start-up process when designing the protection system. Similarly, the protection of all drives must be set up.