POWER MACHINES

creating energy

FOUR-POLE TURBOGENERATORS WITH AN OUTPUT CAPACITY OF 1200 MW AND HIGHER

O.ANTONYOUK, Chief designer of turbogenerators
E.GUREVICH, Dr. of Science, Head of Power-machinery Research Department

OJSC POWER MACHINES BRANCH ELECTROSILA
SAINT-PETERBURG, RUSSIA

2008

- The design of the four-pole turbogenerators with an output capacity of 1200 MW and higher, which are under development nowadays at Electrosila plant, is based on the application of hydrogen-water cooling system.

- Earlier this design was used in 18 generators of 1000 MW, 1500 rpm, 24 kV. They are under operation at the nuclear power plants for more than 20 years.

- The averaged availability ratio of these generators are equal to 0.9983.

- The main achievements are defined by the substantial thermal and mechanical reserves which were attained in the prototype design.

Four-pole hydrogen-water cooled turbogenerator of 1000 MW at the nuclear power station

Some test results

Experimental steady temperatures of active parts and hot cooling mediums at the 1000 MW, cosφ = 0,9 and temperature of cold hydrogen and cold distillate 40^{O}C

Stator winding (max.)	**66 ^{O}C**
Rotor winding (med.)	**86 ^{O}C**
Stator core (max.)	**69 ^{O}C**
Hot hydrogen	**56 ^{O}C**
Hot distillate after stator winding	**62 ^{O}C**

Vibration of the stator winding in the end parts under rated load is less than 30 microns.

To get the same level of durability for the generators of 1200 and 1500 MW, we undertake some additional measures, namely:

1. **Small extension of the main geometrical dimensions of the active parts (diameter and length of the rotor body and stator bore).**

2. **Further intensification of the gas cooling system (mainly in respect of the rotor winding cooling) in order to ensure the thermal reserves to be close to those we have for the prototype.**

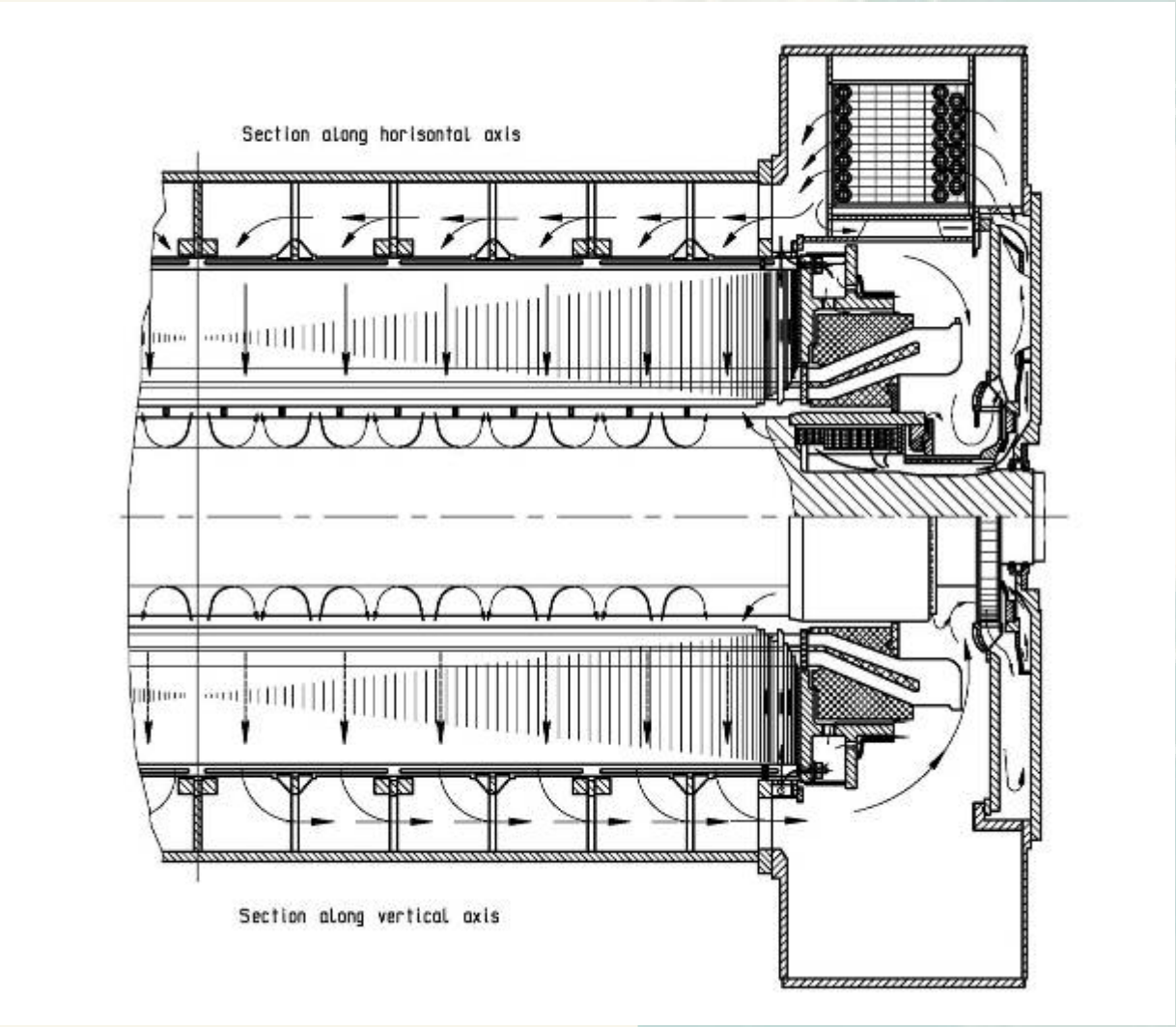
To decrease the rotor winding temperature, we must

increase the gas flow through the rotor cooling ducts
or /and
decrease the temperature of gas entering these ducts.

To **increase the gas flow** through the rotor cooling ducts, we make use of the induced retardation of gas in the air gap by means of
axial barriers, which are mounted at the stator bore side.

To decrease the inlet gas temperature, a certain number of **tangential segregating baffles** are applied in the air gap.
They prevent from penetration of hot gas to cold one before its entrance to rotor.

The radial-tangential stator ventilation system



The radial-tangential stator ventilation system

- ***The cooling gas,***

  first, passes along the stator channels **radially to the air gap,**

  then it goes **tangentially,**

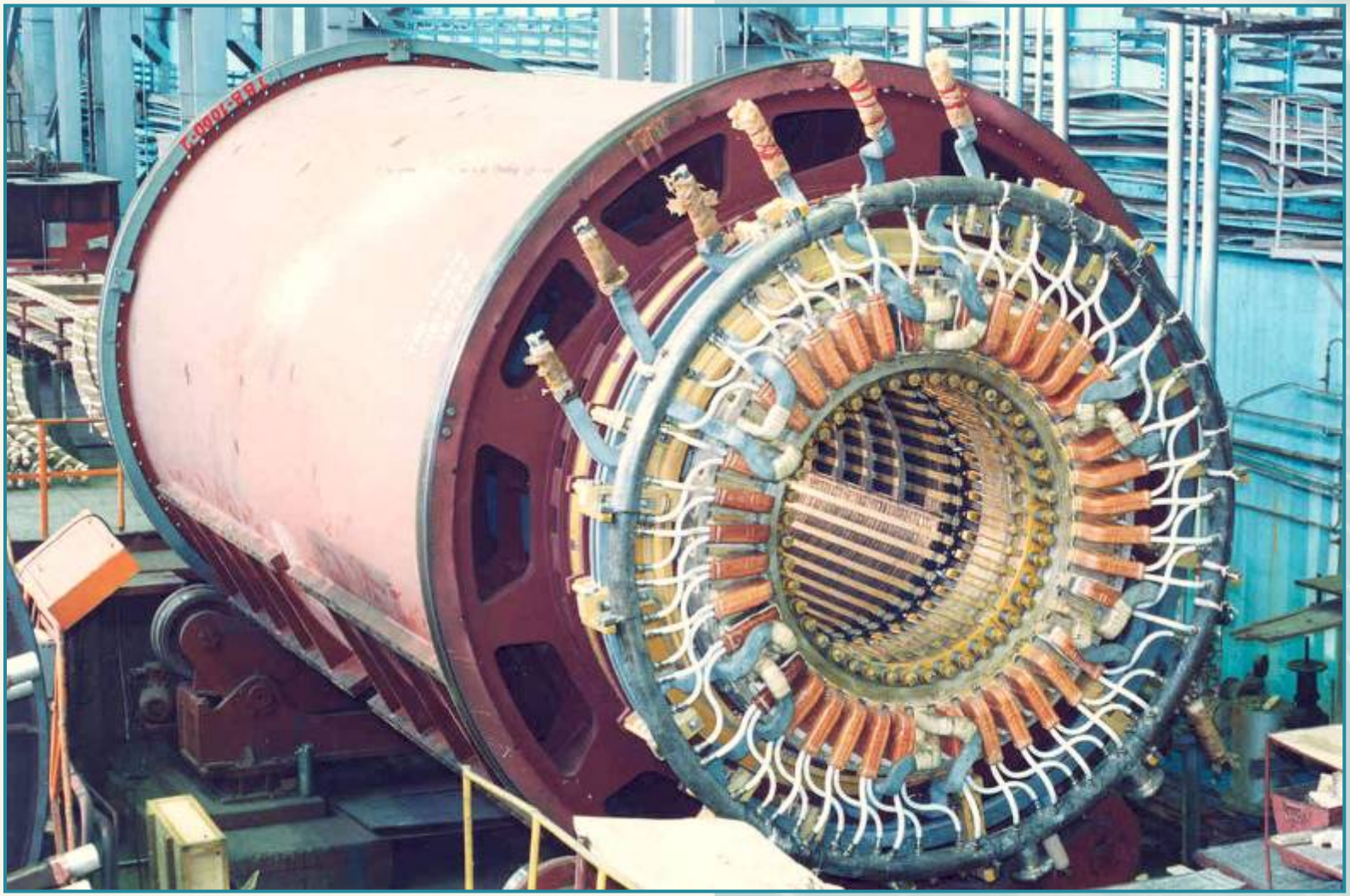
  and further **comes back to the periphery** of the stator**.**

- ***The system includes***

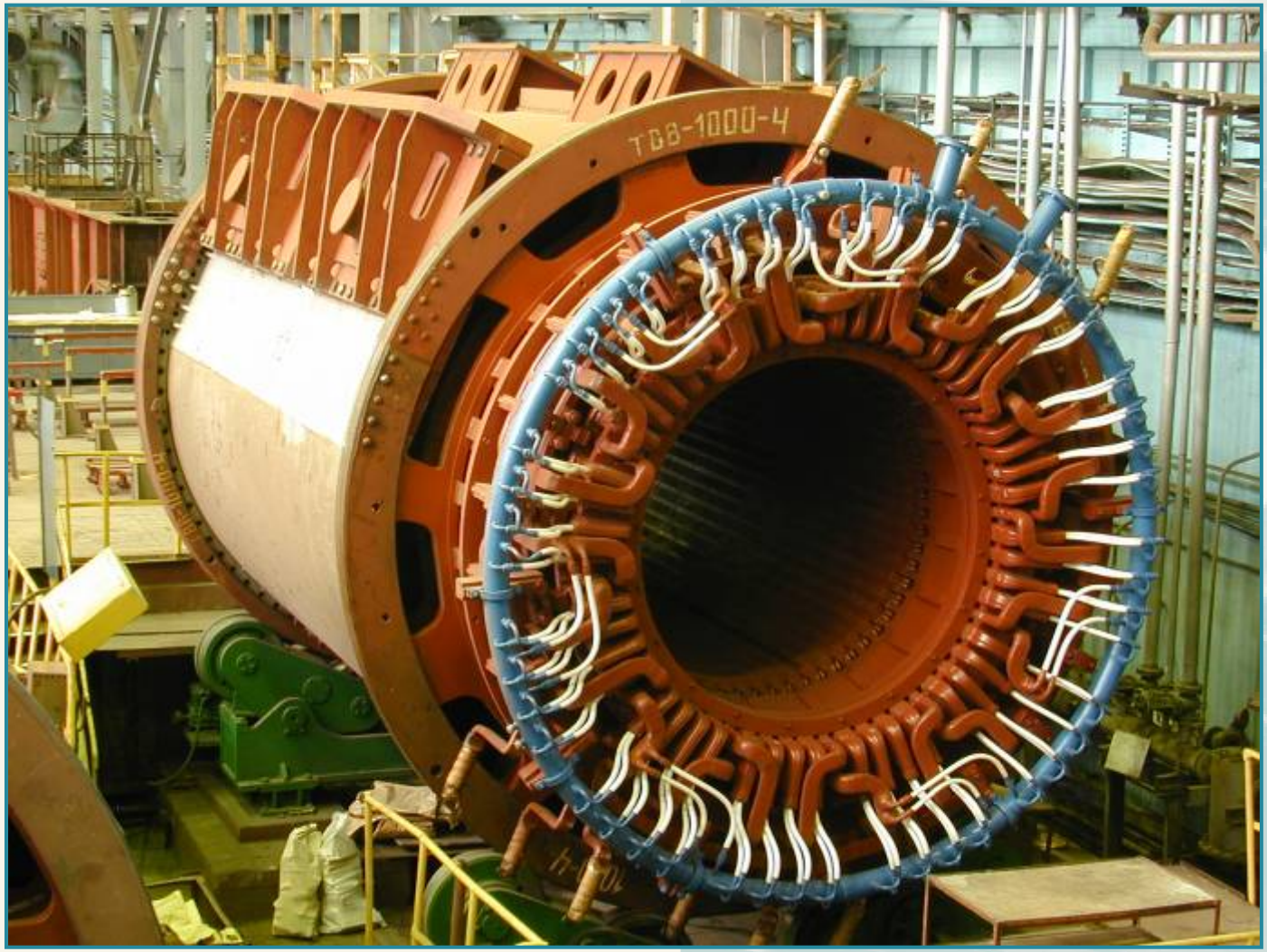
  two axial barriers at the stator inner surface between the opposite zones of the stator ventilation

  several **tangential baffles**, their position is coordinated in axial direction with the zones of rotor ventilation.

Stator of turbogenerator with axial barriers and tangential baffles



Stator of hydrogen-water cooled turbogenerator (prototype)

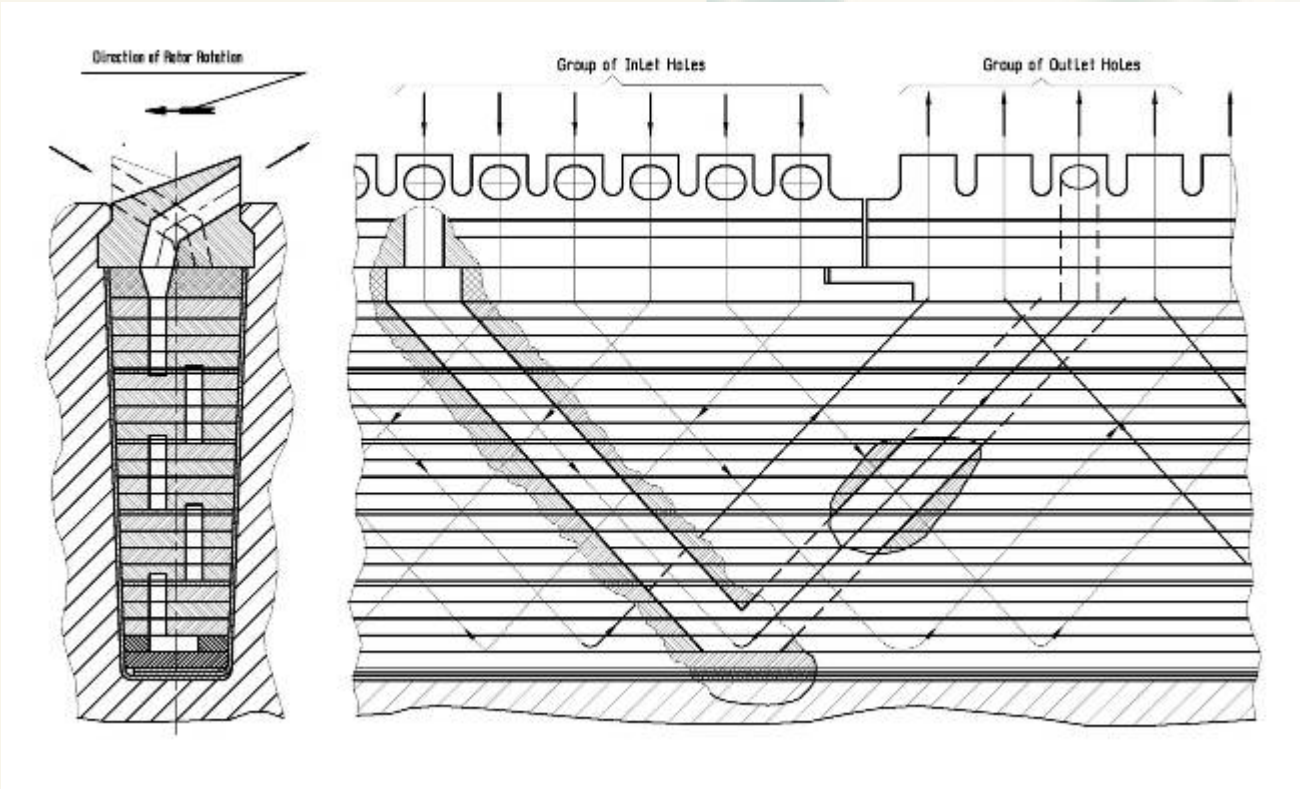


“Air gap pick-up” system

The rotor gas velocity is determined by :

the quality of transformation of the gas flow dynamic pressure into the static one.

the kinetic energy of the slot wedge and gas contacting in the air gap.



The “velocity of contacting” and the system stability

The “velocity of contacting” depends on the mechanical bond between the air gap flow and the rotor. The more curling of the air gap flow, the worse is the rotor ventilating system and, besides, the lower is the stator ventilating system **stability.**

(*The system is a stable one if it is free from any traces of disturbances, for example, inverse flows*).

We need to look after the stability of the ventilating system as applied to the largest generator design. We have studied this phenomenon by means of simulation and full-scale experiments.

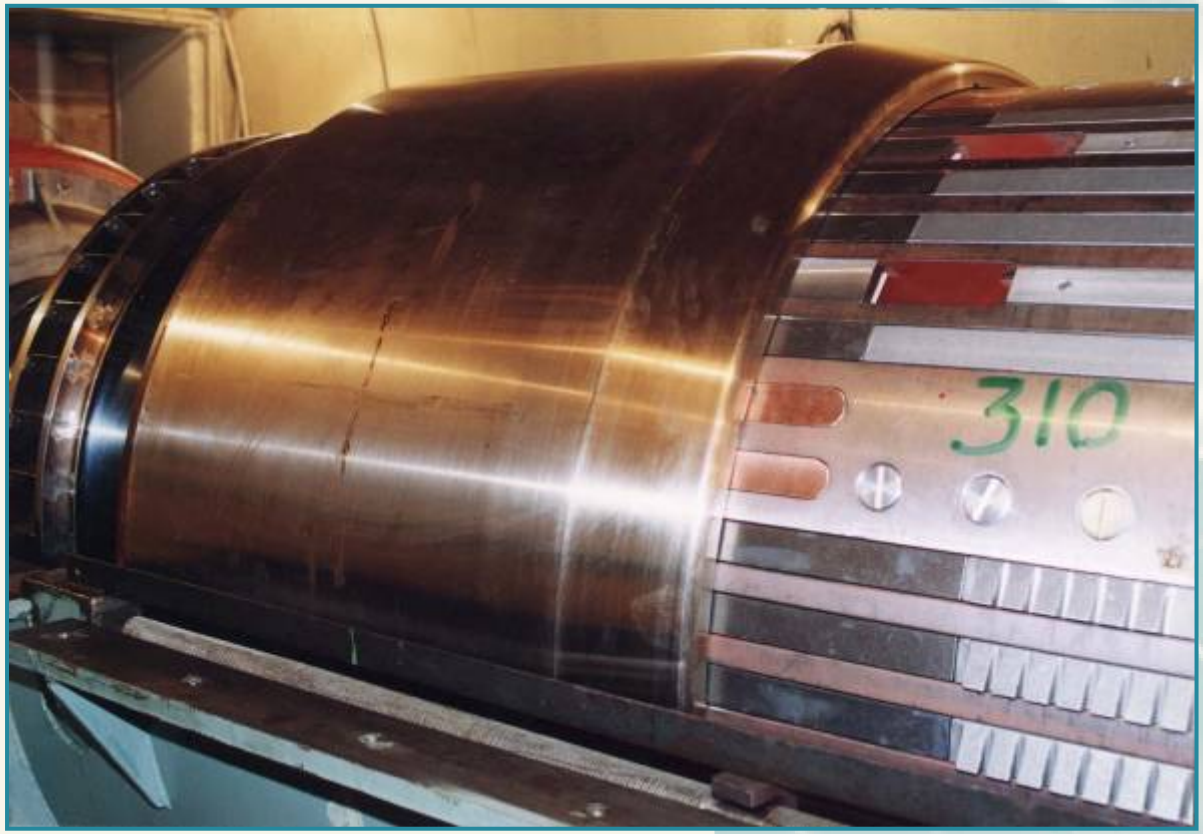
Our **mathematic model** is based on the **momentum balances** in each of the manifold numerous elements of the system.

As to the **experiment, it was realized** on several two-pole and four-pole turbogenerators **at the test rig.**

Testing of hydrogen-water cooled turbogenerator

Built-in centrifugal fans

- The ventilating system behaviour (especially its stability) are greatly influenced by the fan performance characteristics. We have the proved design and experience of producing the built-in centrifugal fans with the straightener blade, which has efficiency of no less than 70%.



Heat transfer factor in the rotor ducts

- An additional positive effect is appeared when aliasing or macro-roughness of the rotor duct walls is made.
- These conditions, which are typical to V-shaped rotating ducts, contribute to the artificial turbulization of a hydrogen flow and to rise of **heat transfer factor** in the duct.
- The final result is a **decrease of rotor winding temperature**.

Two alternatives of the rotor winding ventilating system

- As a matter of fact, we have two alternatives of the rotor winding slot portion self-ventilation, namely
- **air gap pickup**
- **pickup from the rotor subslot duct**.
- These two systems are close in their effectiveness and economy.

From 1000 MW prototype up to 1200&1500 MW turbogenerators

Measure	Purposes	Physical effect
Two axial barriers of the proper height and the proper profile at the stator inner surface between the opposite zones of the stator ventilation	1. To increase the gas velocity through the rotor cooling ducts. 2. To ensure the stator ventilating system stability.	1. Increasing of the kinetic energy of the slot wedge and gas contacting in the air gap. 2. The stator ventilating system is free from any traces of disturbances, for example, inverse flows.
Several tangential baffles at the stator inner surface coordinated in axial direction with the gas zones of rotor	To decrease gas temperature at enter the rotor cooling ducts	Prevention of hot gas penetration to rotor entrance sections
Built-in centrifugal fans (with the straightener blade) of increased pressure drop	To ensure the stator ventilating system stability.	Decreasing of the air gap flow curling, absence of inverse flows in the gas cooling system
Aliasing or macro-roughness of the rotor winding duct walls	To rise of heat transfer factor in the duct	Artificial turbulization of a hydrogen flow in the duct

Conclusion

All physical effects described above were taken into account when designing the new modern powerful four-pole turbogenerators.

At the present time Branch Electrosila carries out **the design and preparation of production for the series of the four-pole generators with an output capacity 1200 and 1500 MW.**

Thus, we have a positive experience of the prototypes operation, the availability of the research-and-development complex and the scheduled expansion of the Electrosila production potentialities.

It permits us **in 3 to 4 years to start the series production** of four-pole turbogenerators with an output capacity 1200 and 1500 MW, in the amounts capable of satisfying the demands of the nuclear power in Russia and abroad.

Thank you for attention