

TRANSPORT SYSTEMS

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CASCADE PLANT OF STEADY AND REGULATED FREQUENCY OF ROTATION

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Existent aircrafts constant-speed drives are considered, and also as an alternative for their replacement is a cascade plant of built-in an aero-engine, its electroscheme, operating principle and basic correlations.

Keywords: airplane, power-supply system, generator, cascade plant.

Introduction. At present on existent aircrafts (C) a stability of generators rotation is provided by constant-speed drives (CSD) [1] placed between an aero-engine (AE) and generator. CSDs of next types are serially used:

- mechanical;
- turbomechanical;
- hydraulic;
- hydromechanical.

Mechanical transmissions of constant rotation frequency. Transmissions of such type are friction reducers with a continuously adjustable gear-ratio (so-called mechanical variators).

The construction arrangement of one of such transmissions varieties is shown in fig. 1. On a driveshaft 3 two leading pulleys 1 and 2 are mounted, which have freedom of the axial moving. By means of rollers 5 and 6 a motion is passed to the driven pulley 4, connected with an output shaft 11 of transmission by means of cartridge 7. Active faces of drive pulleys 1 and 2 and rollers 5 and 6 are part of torus surface. Intermediate rollers 5 and 6 touch drive and driven pulleys in points, distant from the rotation axis in the distance r and R accordingly. If sliding absents between rollers and pulleys, the ratio of rotation frequencies on an output and input of transmission or velocity ratio of reductor equals to the ratio of radiuses of r and R .

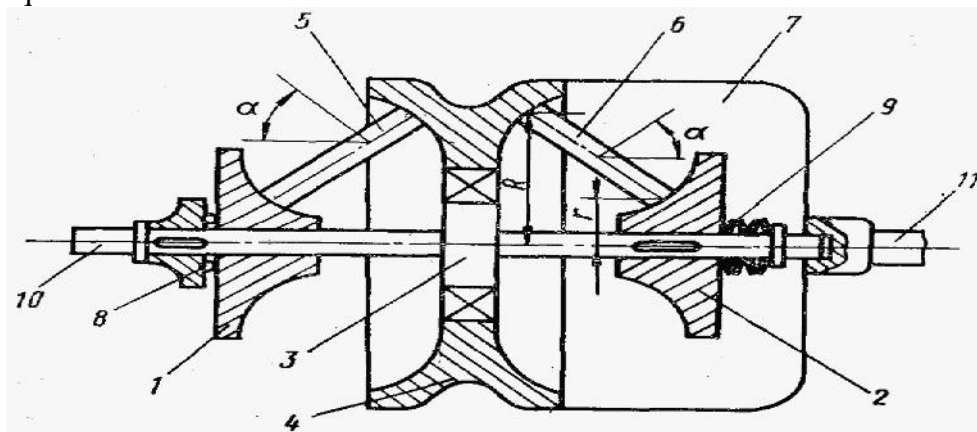


Fig. 1. Mechanical transmission of constant frequency: 1, 2 – drive pulleys; 3 – driveshaft; 4 – driven shaft; 5, 6 – rollers; 7 – cartridge; 8 – regulator of effort; 9 – spring; 10 – input shaft; 11 – output shaft

Values of radiuses of r and R of tangency points, and consequently, and transmission ratio of drive fluently regulated by the change of angle α of rollers slope (turn round axes O and O_1 in a fig. 1). A gear admits running the transmission number to 3...5 times. In fig.1 one pair of rollers 5, 6 is represented, actually them three, located symmetric on the circumference of touch through 120° . Due to the bilateral location of rollers 5, 6 relatively driven pulley a 4 bearing of gear are unloaded from axial efforts.

Drive shaft 3 connected with the input shaft 10 by means of ball-shaped device 8, serving for automatic control of pull effort of rollers against drive and driven pulleys. Preliminary hold-down pressure is carried out by prepressure of elastic washers 9.

Automatic maintenance of constancy of generator rotation frequency is carried out by a hydraulically-driven regulator for the turn of rollers 5 and 6. The turn of rollers, appressed against pulleys, requires considerable efforts and considerable power of executive device. The adjusting system by virtue of it turns out inertia. Variators of similar type can be used both for the drive of direct action and as elements of differential gears.

Although such gears have comparatively high efficiency (0,85...0,9), the acceptable masses (one of drives on generator power 30 kW, output rotation frequency 8000 rev/min at input 3000...10000 rev/min had mass about 40 kg and efficiency 0,85), but they are structurally difficult, have small lifetime (less than 500...800 h), and a wide application was not got.

Turbo mechanical gears of constant rotation frequency. In turbodrive of direct action a generator drive is carried out by an air turbine, taking away air from the compressor of aero-engine. In a turbo mechanical gear (differential) part of power (uncontrolled) is taken off from the engine shaft, and part of power (controlled) for the airily-turbine drive of differential gear is taken off from the compressor of aero-engine [2] as energy of the compressed air.

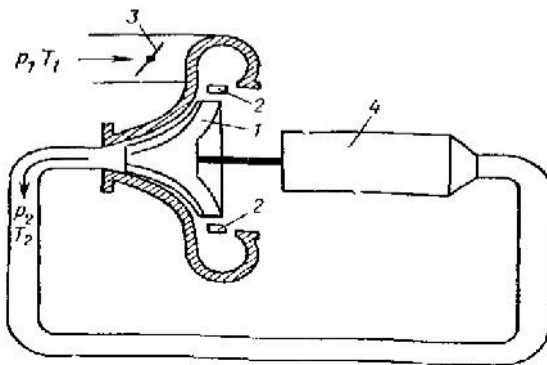


Fig. 2. Chart of generator drive from air turbines:
1 – wheel of turbine; 2 – set of a nozzles; 3 – dam;
4 – generator

In a fig. 2 a principal scheme of direct action drive from an air turbine is brought, which takes away air from the aero-engine compressor. Air, taken away from the aero-engine compressor with parameters (p_1, T_1) , arrives to the input of set of nozzles of turbine 2. In the set of nozzles this air expands, its total heat falls as a result, and the velocity of travel grows. From the set of nozzles output an air, possessing large kinetic energy, acts on the blades of driving wheel of turbine 1, where kinetic energy of air will be converted in mechanical. Going out a turbine air has LP of p_2 and subzero temperature of T_2 and can be used for cooling generator 4.

For the drive of generators the turbines of different types are used.

Depending on the place of transformation of thermal energy of air in kinetic, turbines are divided into active and reactive. In active turbines transformation of thermal energy of air to kinetic one takes place in a set of nozzles, and in the driving wheel of turbine there is only converting of kinetic energy into mechanical. In reactive turbines thermal energy of air is converted in kinetic energy both in a set of nozzles and in a driving wheel. On the driving wheel of reactive turbine there are the use of kinetic energy of air and further process of its expansion.

By direction of air stream in a turbine they are divided into axial and radial.

Radial turbines in which a working air stream is directed perpendicularly to axes of rotation are divided into centrifugal and centripetal. Centripetal turbines as compared to centrifugal have higher efficiency, that is explained by the best use in them of kinetic energy of air on the blades of driving wheel.

By the method of controlling air turbines are divided into turbines with a jet and throttle control. At the jet control the change of air expense through turbines is carried out by means of diminishing of nozzle area, at throttle – by means of throttle flap, set on an input or output of turbine. More economical is the jet control.

The joint of turbine with the generator shaft is mostly done through a lowering reductor, because turbines on LFS of rotation (12000...15000 rev/min) turn out inefficient, and implementation of generators on large frequencies of rotation presents large difficulties because unreliable operation of bearing.

Turbo mechanical differential gear. The gear of constant frequency (fig. 3) consists of active axial turbine 1, differential reducing gear and control system.

A differential reducing gear consists of sun gear 3, connected through gearwheels 4 and 5 with the shaft of turbine, three planetary pinions 6, carrier 7, connected by a spring 15 with the drive shaft of engine, and crown gear 8, connected through gearwheels 10, 11 and 12 with the generator rotor. Constant rotation frequency of generator is supported by a centrifugal regulator the sensor of which is driven to the rotation by a gearwheel 10 through gearwheels 9, 14, 13 and revolved with frequency proportional frequency of generator rotor rotation. For the regulator feed with oil an oil pump 16 is used, led from a gearwheel 9.

At deviation of generator rotation frequency from a rated value a regulator 23 turns a regulative dam 17, placed in a turbine input, changing the air expense through it. Cut-in and cut-off of gear is produced by means of starting throttle flap 19, which is operated by starting servopiston 20, guided by means of controller 24.

The regulator of angular speed has a centrifugal sensor. The gear of constant rotation frequency is assembled on the gear-box of airplane, has an output spring, connected with the drive shaft of gear-box of aero-engine.

Operation principle of gear consists in the following.

Maintenance of constant generator rotation frequency, recipient the basic fraction of power from the drive shaft of aero-engine, is carried out by a turbine through a differential reducing gear, frequency of rotation of which changes at the change of aero-engine rotation frequency under law $n_G = n_{eng} + n_T$.

In the range of drive shaft rotation frequencies 2745...4200 rev/min the generator shaft is supplied through a differential reducing gear simultaneously with two sources from a drive shaft 15 and from a turbine 1.

At the increase of rotation frequency of drive shaft n_{eng} a frequency of turbine rotation n_T , necessary for maintenance of generator constant frequency, diminishes and under reaching frequency of drive shaft rotation $n_{eng} = 4200$ rev/min becomes equal to the zero.

In the range of drive shaft rotation frequency from 4200 to 4860 rev/min a turbine operates in the mode of brake, revolved in reverse direction and reducing part of power, going from a drive shaft. During turbine brake mode operating air goes through a turbine in the same direction, what at the ordinary modes of turbine, creating a torque moment on a turbine, counterbalancing loading on a generator. Passing to the brake mode and further operation in this mode takes place automatically by means of frequency regulator, controlling a still regulative dam on input in a turbine. Only at high-frequency enough of drive shaft rotation and small generator load the expense of air through a turbine, necessary for the transmission of torque moment, becomes equal to the zero. On these modes a regulative dam is fully closed, and loading on a generator is counterbalanced by windage to the revolved wheel of turbine. At the further diminishing of generator load or further increase of drive shaft rotation frequency a windage on the wheel of turbine becomes too large.

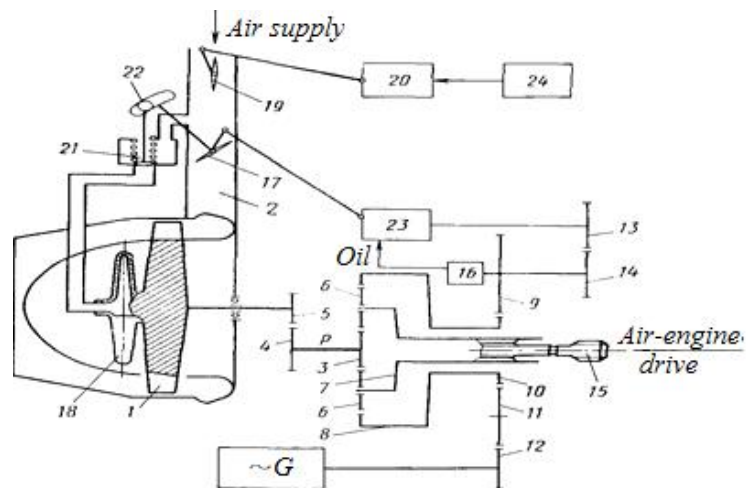


Fig. 3. Chart of turbo mechanical differential gear of constant rotation frequency: 1 – wheel of turbine; 2 – air-channel; 3 – sun gear; 4, 5 – gearwheels; 6 – planetary pinions; 7 – carrier; 8 – crown gear; 9 – 14 – gearwheels; 15 – spring of drive; 16 – oil pump; 17 – dam; 18 – Segner's wheel; 19 – dam; 20 – servomechanism; 21 – valve; 22 – control mechanism; 23 – regulator of rotation frequency; 24 – controller

For operation on such modes (for diminishing of resistance moment) Segner's wheel 18 is set on the wheel of turbine, to which air is given through the special valve 21, guided by the same frequency regulator through the mechanism of control speed 22 after the complete closing of regulative dam. Segner's wheel helps to the turbine wheel to be revolved, overcoming windage.

Hydraulic gears of constant rotation frequency. Hydraulic gears are used also two types: direct action and differential. The most wide distribution was got by differential gears. Hydraulic gears consist of two machines: hydraulic pump and hydromotor. Hydraulic machines are used both with plunger and with ball-shaped pistons. Greater application in hydraulic gears for the drive of aviation alternators got plunger machines because some more simple technology and large experience of their making [3].

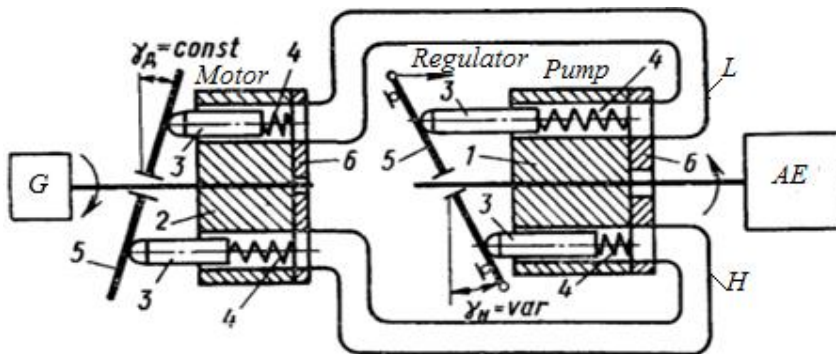


Fig. 4. Principal chart of direct hydraulic gear with a plunger pump and motor: 1 – rotor of hydraulic pump; 2 – rotor of hydromotor; 3 – plunger; 4 – recurrent spring; 5 – swash plate; 6 – distributive disk

In a fig. 4 a principal chart of direct hydraulic gear is brought with a plunger hydraulic pump and hydromotor. It consists of hydraulic pump *HP*, connected with the shaft of primary engine of *AE* and hydromotor, connected with the generator *G* shaft. In the rotors of hydraulic pump 1 and hydromotor 2 there are equispaced on a circumference cylindrical chambers in which plungers 3 and recurrent springs 4 are.

At the rotation of hydraulic pump rotor the plungers, running in a swashplate 5, move recurrently-forward, here springs wring out plungers toward a swashplate. From other side of hydraulic pump rotor an immobile distributive disk 6 is set, which communicates the chambers of rotor by turns with the main pipe of high (*H*) and low (*L*) pressure. This disk has two arc holes with the corner of circumference 150°, which admission and taking of hydromixture are carried out through.

During the rotor rotation of pump at moving of plungers toward a disk due to wringing out by their springs a hydromixture is sucked in the cylindrical holes from the main pipe of *LP*, and then at the further rotor rotation (next half of turn) plungers, rest against a swashplate, move in reverse direction and push a hydromixture in a main pipe of high-pressure. The productivity of pump depends on position of swashplate (ρ) and frequency of rotation. Changing the slope angle (ρ), it is possible fluently to regulate the productivity of pump. When corner $\rho = 0$, a piston stroke is equal to the zero and the productivity of pump is also equal to the zero. A hydromotor has an analogical design, only swashplate 5 unlike a hydraulic pump has a constant angle of slope m . A hydromixture, acting from a main pipe of high-pressure presently in part of chambers (half of chambers) of hydromotor rotor, force out plungers, which, rest against a swashplate, press on it with force F . Tangential forces of F appear as a result, and, so, torque rotating the rotor of hydromotor. Thus, there is a rotation of hydromotor rotor.

Differential gears are used in swingeing majority of cases which have considerably greater efficiency and less weight as compared to direct gears.

Hydromechanical gears of constant rotation frequency. In a fig. 5 a chart of hydromechanical differential gear is brought. The shaft of primary engine of *AE* revolves the rotor of hydraulic pump 1 and carrier 5 of planetary gearbox. Shaft of generator *G* is connected with the sun gear 7 of reductor, and rotor of hydromotor 8 connected with the crown gear of reductor. At vertical position of swashplate, when $\rho = 0$, the pistons of hydraulic pump are immobile (in recurrently-forward motion), a hydromixture is not pumped over, the rotor of hydromotor is immobile, the mode of the pilot-operated check valve takes place.

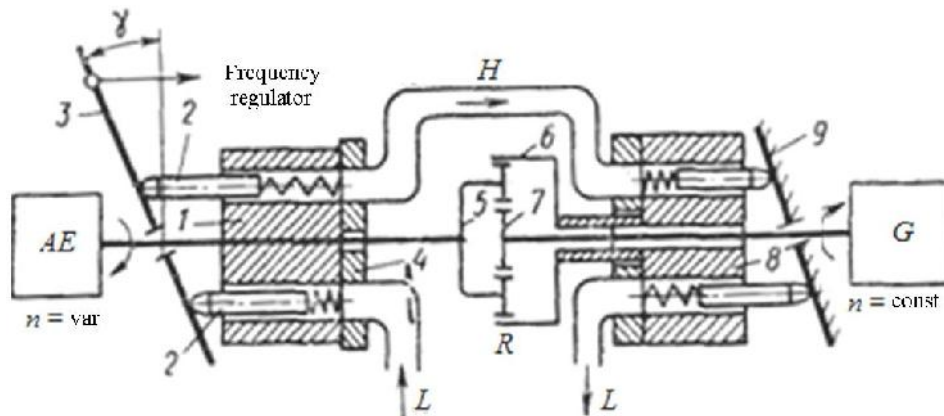


Fig. 5. Chart of hydromechanical differential gear: 1 – rotor of hydraulic pump; 2 – plunger; 3 – swashplate; 4 – distributive disk; 5 – carrier; 6 – crown gear; 7 – sun gear; 8 – rotor of hydromotor; 9 – swashplate; AE – primary engine; G – generator; L – main pipe of low pressure; H – main pipe of high-pressure

Thus crown gear 6 immobile and the rotation of primary engine shaft is passed directly to the generator shaft. Such mode is expedient at cruising speed of flight, on which flight is produced most long time. Thus frequency of generator rotation must be equal synchronous. At a speed-down primary engine swashplate 3 must be declined to the left (> 0), here hydraulic pump, pumping a hydromixture from the main pump of LP in a main pump of high-pressure, will force to be revolved the rotor of hydromotor, that will result in the increase of generator rotation frequency to the synchronous value. In this mode part of power is passed through the hydraulic system. At the increase of primary engine rotation frequency higher than synchronous frequency of generator position of mad must be changed on position to the right of neutral (< 0) here a hydromotor will pass to the mode of hydraulic pump, and hydraulic pump in the mode of hydromotor. Rotor 8 will change a rotation on reverse. Frequency of generator shaft rotation will be less frequency of primary engine rotation, and part of power returns on the primary engine shaft back through the hydraulic system.

Hydromechanical differential gear due to comparatively high efficiency (85÷90%), to small mass (36 kg for a generator by power 40 A at $n = 6000$ rev/min), widely used on the American and English airplanes. However experience of exploitation of hydrogears educed the row of their substantial defects. The cost of hydrogears is very high, setting of it and adjusting on a primary engine is extraordinarily difficult. Labour intensiveness of major repairs of source with hydrogear in 2,5 time higher than labour intensiveness of major repairs of direct-current source. On the stake of hydrogears is more than 50% of all faults in the system of power supply.

The incorporated block-drive and generator are presently created in a common frame and with the general oil system. Oil is used not only for a drive but also for cooling of generator.

Cascade plant. The criterion of aircraft perfection are an economy and power (fuel) efficiency. It can be attained by the small expense of fuel (renunciation from the air takeoff), and also minimizing mechanical power takeoff from an aero-engine (renunciation from constant-speed drive).

Especially evidently these advantages will appear in case of realization of starter-generator built-into AE (fig. 6). The built-in generating plant (GP) diminishes also an aerodynamic drag of AE [2].

However built-in GP will have a large diameter of rotor, as placed on a shaft of TE, and so, large sizes and mass (approximately on 20...50 %), however due to the withdrawal of drive and box of auxiliary units a general height of GP mass will not be.

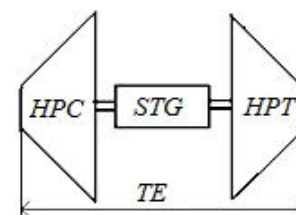


Fig. 6. Starter-generator (STG) built into AE: HPC – high-pressure compressor; HPT – high-pressure turbine; TE – turbine engine

Built-in GP will simplify all system of secondary energy supply and will provide a considerable economic effect (efficiency will increase on 9...11 %, and trouble-free life – in 10 times and more). It will allow to combine maintenances of GP with major repairs of TE.

Most effect from built-in GP it is possible to get, if to execute it nonregulated after voltage and frequency, and to provide necessary quality of electric power due to individual secondary sources for every group of users.

It is known that the mass and overall dimensions of GP diminish with the increase of rotation frequency. If to combine a built-in GP with the semiconductor secondary sources of electric power, then it is desirable to increase rotation frequency of GP (to 30...50) · 10³ rev/min. To provide such rotation frequency for built-in GP problematically, and that is why it is needed to make an effort find the methods of receipt of high frequency at LF of rotor rotation.

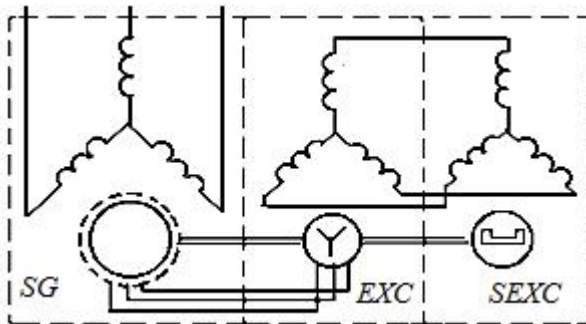


Fig. 7. Electrical scheme of GP:
SG – synchronous generator; EXC – exciter;
SEXC – subexciter

The multipolarity of generator decides this problem, but mass and overall dimensions get worse here. Solving this contradiction is possible due to excitation of generator by alternating current. Thus the angular speed of magnetic-field in an air gap will be determined by the sum of the field speed in relation to a rotor and rotor speed in space. If to execute GP under a chart, shown in a fig. 7, then an excitation noninteraction, contact free and high-frequency of output voltage at LF of rotor rotation is here arrived.

Frequency of output voltage in this GP is determined by such correlations:

$$f_{SG} = \frac{p_{SG}}{2\pi} (\Omega + \Omega_{rel}) = \frac{p_{SG}}{2\pi} \left(\Omega + \frac{2\pi}{p_{SG}} f_{exc} \right) = \frac{p_{SG}}{2\pi} \left[\Omega + \frac{2\pi}{p_{SG}} \frac{p_{exc}}{2\pi} \left(\Omega + \frac{2\pi}{p_{exc}} \frac{p_{sexc}}{2\pi} \Omega \right) \right] =$$

$$= \frac{p_{SG}}{2\pi} \left[\Omega + \Omega \left(\frac{p_{exc}}{p_{SG}} + \frac{p_{sexc}}{p_{SG}} \right) \right] = \frac{\Omega}{2\pi} (p_{SG} + p_{exc} + p_{sexc}),$$

where $p_{SG}, p_{exc}, p_{sexc}$ is a number of poles pair accordingly of synchronous generator, exciter and subexciter; Ω – angular speed of rotor; Ω_{rel} – angular speed of synchronous generator field in relation to a rotor.

So, necessary frequency of output voltage can be got choosing of both number of poles pair and quantity of exciters in GP.

If GP must have the regulated voltage and frequency, then it is possible to apply a cascade plant [4], represented in a fig. 8.

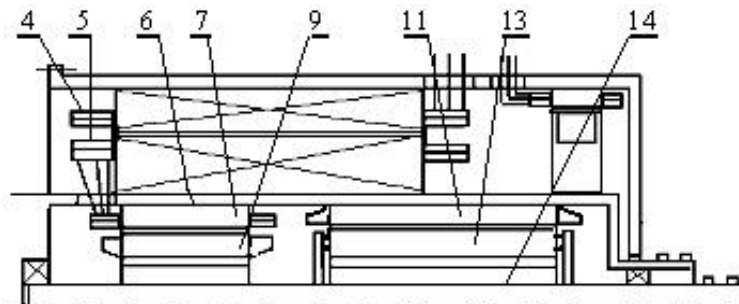


Fig. 8. Principle construction arrangement of cascade plant: 4 – armature of SG; 5 – inductor of SG;
6 – rotor of SG; 7 – armature of SGDR; 9 – inductor of SGDR; 11 – armature of AAM; 13 – rotor of AAM;
14 – driven shaft

Electrical schematic of this plant represented in a fig. 9. Various cascade plants are examined in a paper [5].

A plant contains an asynchronous-synchronous machine () 1 with stator and rotor 3 (with multiphase windings 4 and 5, fig. 8), set on the driveshaft 6. Rotor winding 3 connected to armature 7 of synchronous generator of double rotation (SGDR) 8 with an inductor 9. Additional asynchronous machine (AAM) 10 has an armature 11 of a pole-commutated winding 12 and squirrel-cage rotor 13.

Armature 7 of SGDR 8 and armature 11 of AAM 10 are set on a driveshaft 6, and inductor 9 and squirrel-cage rotor 13 – on the driven shaft 14. Winding 12 connected through regulator 15 to the winding 2.

A cascade plant operates so. Drive-shaft 6 has arbitrary frequency of rotation n_1 , rotation frequency of driven shaft n_2 is

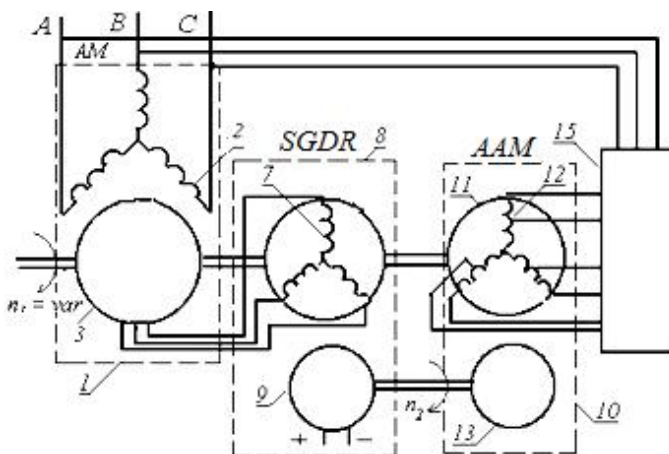


Fig. 9. Principle electrical scheme of cascade plant: 1 – asynchronous-synchronous machine; 8 – synchronous generator of double rotation; 10 – additional asynchronous machine; 15 – regulator

regulated. Asynchronous machine 1 operates as a generator, excited by a current with frequency of sliding. Frequency of rotation of field in space equals to the algebraic sum of mechanical rotation frequency of driveshaft and electric frequency of sliding.

Synchronous generator of double rotation 8 operates as a generator, producing the current of sliding frequency for AM excitation, and as an electromagnetic muff of sliding, revolving a driven shaft. Regulated pole-commutated 10 of double rotation operates as an asynchronous muff of sliding and asynchronous generator, creating a brake moment on the driven shaft. Voltage of is regulated by the change of excitation current of SGDR.

Frequency of armature winding is determined by equation: $f_{AM} = f_1 + f_{sl}$, where

$$f_1 = \frac{p_{AM}}{60} n_1, f_{sl} = \frac{p_{SGDR}(n_1 - n_2)}{60}; p_{AM}, p_{SGDR} - \text{a number of poles pair accordingly of and SGDR.}$$

$$\text{Then } f_{AM} = \frac{n_1(p_{AM} + p_{SGDR}) - n_2 p_{SGDR}}{60}.$$

Thus, changing frequency of rotation n_1 , frequency of EMF, induced in the armature winding of , it is possible to stabilize by the change of n_2 . Correlation of number of poles pair of and SGDR can be arbitrary, but at large p_{SGDR} a regulated AAM must be counted on a large brake moment.

The sum of brake electromagnetic moment of AAM and friction moment of driven shaft in the steady operation mode equals to the traction electromagnetic moment of SGDR.

$$M_{SGDR} = M_{AAM} + M_{F_2}.$$

The additional asynchronous machine of double rotation operates simultaneously in the modes of asynchronous muffs of sliding and generator. For diminishing of sliding losses an AAM is executed pole-commutated. On the first step the winding of AAM is switched-on less poles pair. Thus frequencies of field rotation relative to the driveshaft of AAM and in space accordingly are equal to:

$$n_{ral} = \frac{60 f_{AM}}{p_{AAM1}} = \frac{n_1(p_{AM} + p_{SGDR}) - n_2 p_{SGDR}}{p_{AAM1}}; n_{sp} = n_1 - n_{ral} = \frac{n_1(p_{AAM1} - p_{AM} - p_{SGDR}) + n_2 p_{SGDR}}{p_{AAM1}},$$

where p_{AAM1} is a less number of poles pair of AAM.

If $p_{AAM1} < (p_{AM} + p_{SGDR})$, then the brake mode of plugging is provided.

On the second step a $2p_{AAM1}$ of poles pair is included and AAM passes to the generator mode,

sending active power in a network and getting a reactive-power from for creation of magnetic flux. Switching on the greater number of poles pair takes place, if rotation frequency of driven shaft

$$n_{22} = 1,03 \frac{60 f_{AM}}{P_{AAM2}} = 1,03 \frac{n_1(p_{AM} + p_{SGDR}) - n_2 p_{SGDR}}{P_{AAM2}}.$$

Power of consists of transformer share, proportional to sliding of driven rotor relative to drive rotor, and generator share, proportional to rotation frequency of drive rotor. Power of *SGDR* is approximately equal to transformer power of and determined by equations:

$$Q_{SGDR} = (Q_{AM} + Q_{nw}) \frac{f_{sl}}{f_{nw}} = S_{nom} (\sin \varphi_{AM} + \sin \varphi_{nw}) \frac{f_{sl}}{f_{nw}}; P_{SGDR} = S_{nom} \cos \varphi_{nw} \frac{f_{sl}}{f_{nw}};$$

$$S_{SGDR} = \sqrt{Q_{SGDR}^2 + P_{SGDR}^2},$$

where $\cos \varphi_{nw}$ – coefficient of active-power of network; $\sin \varphi_{AM}$ – coefficient of reactive-power of ; S_{nom} – nominal power of .

Design electric power of

$$S_{el} = \frac{P_{m2} n_{rl}}{(1-s) \cos \varphi_{AAM} n_{fl}} = \frac{P_{m2}}{(1-s) \cos \varphi_{AAM}} \frac{1}{\frac{n_1 p_{AAM}}{n_1(p_{AM} + p_{SGDR}) - n_2 p_{SGDR}}},$$

where P_{m2} – mechanical power of driven rotor of *SGDR*; $\cos \varphi_{AAM}$ – power-factor of *AAM*;

$$s = \frac{n_{fl} - n_2}{n_{fl}} = 1 - \frac{n_2 p_{AAM}}{n_1(p_{AAM} - p_{AM}) - (n_1 - n_2) p_{SGDR}} - \text{sliding of } AAM.$$

Power of sliding losses: $P_{sl} = P_{m2} \frac{1}{1-s}$.

Choice of poles pair number of machines which are included in the plant, depends on the range of *AE* rotation frequency. If $n_{AM \max}$ 12000 rev/min, then $p_{AM} = 2$. At the wide enough range of *AE* rotation frequency a plugging of *AAM* on the first step is provided by a condition $p_{AAM1} < (p_{AM} + p_{SGDR})$.

For diminishing of *AAM* brake moment it is expedient to take the number of *SGDR* poles pair less, but $p_{SGDR} = 1$, as here would be to transfer *AAM* in the traction mode. In the mode of plugging at some n_1 takes place $n_{fl} = n_1 - n_{rl} = 0$, id est

$$n_{fl} = \frac{n_1(p_{AAM1} - p_{AM} - p_{SGDR}) + n_2 p_{SGDR}}{P_{AAM1}} = 0.$$

On this basis, and also for providing of necessary correlation $\frac{n_1}{n_2}(p_{AAM1} - p_{AM} - p_{SGDR}) = -p_{SGDR}$ in order to receive necessary sliding frequency of *SGDR* it is necessary to choose $p_{SGDR} = 2$ and $p_{AAM} = 3$. Thus $n_1/n_2 = 2$.

On the second step for transfer of *AAM* in the generator mode it is necessary to take $p_{AAM2} = 2$.

Application of cascade plant is expediently at correlation of $n_{1\max}/n_{1\min} = 1,5$, that according to calculations allows to increase specific power of plant. At $n_{1\max}/n_{1\min} = 2$ sliding losses it is possible to decrease in *AAM*, using on *AAM* drive rotor another winding with the number of poles pair $p_{AAM3} > p_{AAM2}$. To the third step they pass, if rotation frequency

$$n_{23} = 1,03 \frac{60 f_{nw}}{P_{AAM3}} = 1,03 \frac{n_1(p_{AM} + p_{SGDR}) - n_2 p_{SGDR}}{P_{AAM3}}.$$

Loading on plant bearing is a small, because the auxiliary machines of small power are placed on a driven shaft, and a driven shaft is revolved approximately with the same speed, what driveshaft.

A plant has large possibilities of poles quantity choice of synchronous generator inductor, that facilitates making.

Conclusions. By the lack of all *CSD*, from the point of view of production, there is a necessity of combination of high-tech of metal treatment and air takeoff from a *AE* compressor, that it is difficult to co-ordinate the production of electric machines with relatively simple technologies. Therefore application of electromechanics plant of constant and regulated frequency, the production of which can be organized at any electric machinery plant and cost of which as at making so during exploitation there will be incomparably less cost of most widespread integral generator plant.

A cascade plant with the regulated voltage and frequency can be built into *AE* and to have identical terms of routine maintenance with it. The contact group of poles number switching of *AAM* operates episodically, and brushes in the contour of *SGDR* inductor rated at power approximately 0,03 of cascade plant power, that must not cause difficulties of exploitation. Certainly, sliding contacts are not desirable in any case and this problem will be solve in future.

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