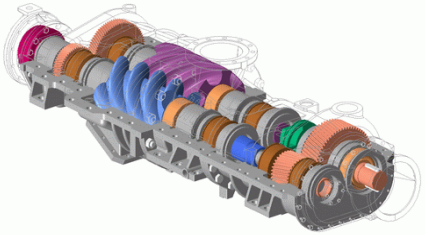
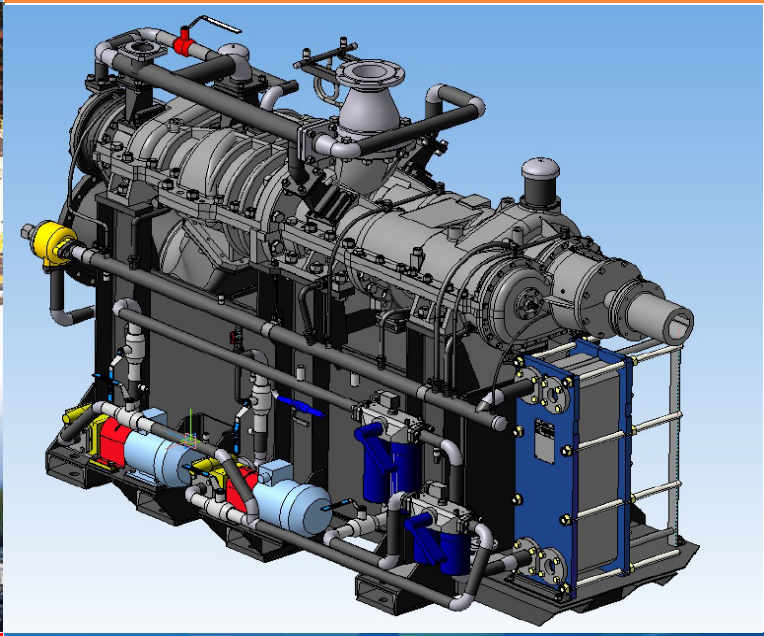
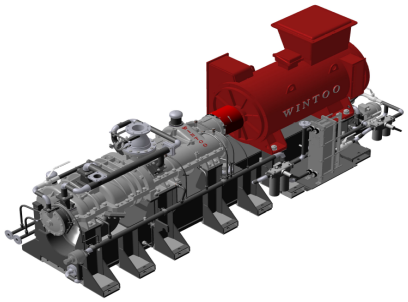
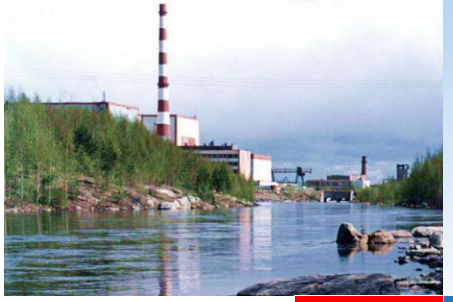


LLC "VT Technology"







INTRODUCTION OF SCREW ROTOR STEAM ENGINES AT THERMAL POWER GENERATION FACILITIES

St. Petersburg ,
Russia
2015

TECHNOLOGY OF SCREW ROTOR STEAM ENGINES (SRSE) UTILIZATION

The technology involves using steam pressure energy for generating electric energy for auxiliary power supply. It may be used in boiler rooms, household waste incineration plants, timber processing industry and agricultural waste incineration plants. SRSEs may be also installed at heat extraction outlets of large turbines installed at thermal power generating facilities.

The SRSE technology is protected by the following patents:
- Invention patent No. 2374455 "Screw Rotor Steam Engine"
- Utility model patent No. 89614 "Screw Rotor Steam Engine"
- Invention patent No. 2303702 "Power Plant".

The power plant permits to utilize excess energy of throttled steam efficiently and to obtained mechanical energy used for generating electricity. Whereupon the supplementary amount of fuel consumed by power facility boilers amounts to approximately 135 grams of equivalent fuel per 1 kWh of produced electric energy.

The plant is very easy to operate and maintain, it is compact in size, has a long service life, it is serviceable, safe and it can operate on poor quality steam.

The equipment used has been certified, it has got positive opinions of Federal research experts based on the results of comprehensive introduction of mini thermal power stations based on SRSEs. The plant is not supervisable by the Federal Service for Environmental, Technological, and Nuclear Supervision bodies; this fact is confirmed by an appropriate letter.

Joint production of electric power does not impede the operation of the main power plant. After having been used in a SRSE, the steam whose thermodynamic parameters are sufficient for use on primary purpose is used for process needs and fed to heat exchangers.

FEATURE OF NOVELTY:

As a matter of fact, a screw rotor steam engine is a new type of steam engine. The SRSE is a volume action engine. The progressive feature of the idea of a screw rotor engine is the same direction (rotational) motion of the engine moving parts. Since the SRSEs has no reciprocally moving parts, rotors can rotate at high speeds, obtaining relatively high power at small dimensions.

SOLUTION EXISTING AT THE MARKET:

There are gas turbine, gas reciprocating and diesel-powered cogeneration plants. Backpressure steam turbines are vane type ones.

KEY DIFFERENCE BETWEEN THE PROJECT AND THE SOLUTIONS EXISTING AT THE MARKET:

The screw rotor steam engine (SRSE) is structurally different from vane turbines and other solutions. The progressive feature of the idea of screw rotor engine is the same direction (rotational) motion of the engine moving parts. Since the SRSEs has no reciprocally moving parts, rotors can rotate at high speeds, obtaining relatively high power at small dimensions. It is important if the SRSE is to be installed in an existing boiler room.
The principal advantage of the SRSE power plant as compared to the steam turbine power plants available t the market is as follows: the existing plants are designed to have virtually the same relationship between steam flows and pressures at the engine inlet and outlet. This set of steaming conditions determines the engine power. The SRSE can adapt to specific conditions of facilities in a wide range; as a result, its power can range between 200 and 1000 kW.

The SRSE has a number of advantages as compared to low power vane steam turbines:

- **high internal relative efficiency** over a wide range of loads;

- **adaptability to low-quality steam**, including highly water charged one. An analogous TG requires at least 0.999 quality of wet steam used. This is attained with the help of a steam superheater (for overheating steam by 30-50 degrees) or a separator;

- **good dynamics and controllability**, it is possible to shutdown the SRSE unit frequently in case operational needs requires it;

- **operation reliability:** long total service live, high repairability because of simple design, long time between overhauls thanks to absence of erosive and mechanical wear of screw rotors and a mechanism protecting thrust bearers from extreme axial loads;

- **small weight:** a unit based on SRSC-1000 (power 1000 kW) amounts weighs 8900 t, a Kuban-0.75 TG (power 750 kW) weighs 13,640 t +/-5%

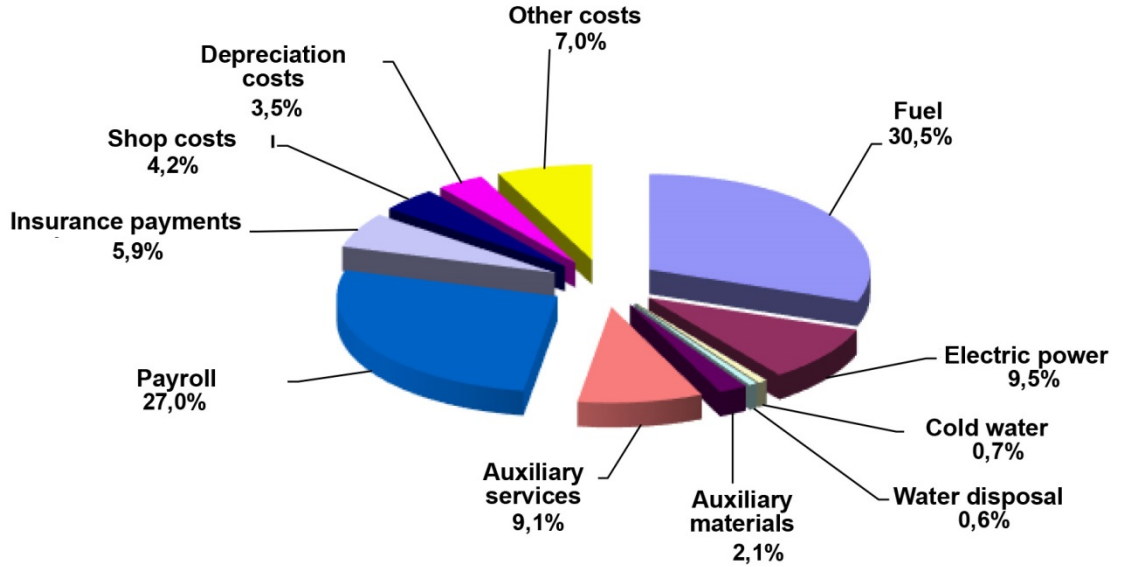
- **easy operation:** the engine does not have any assemblies that need accurate adjustment in the process of operation or complex maintenance;

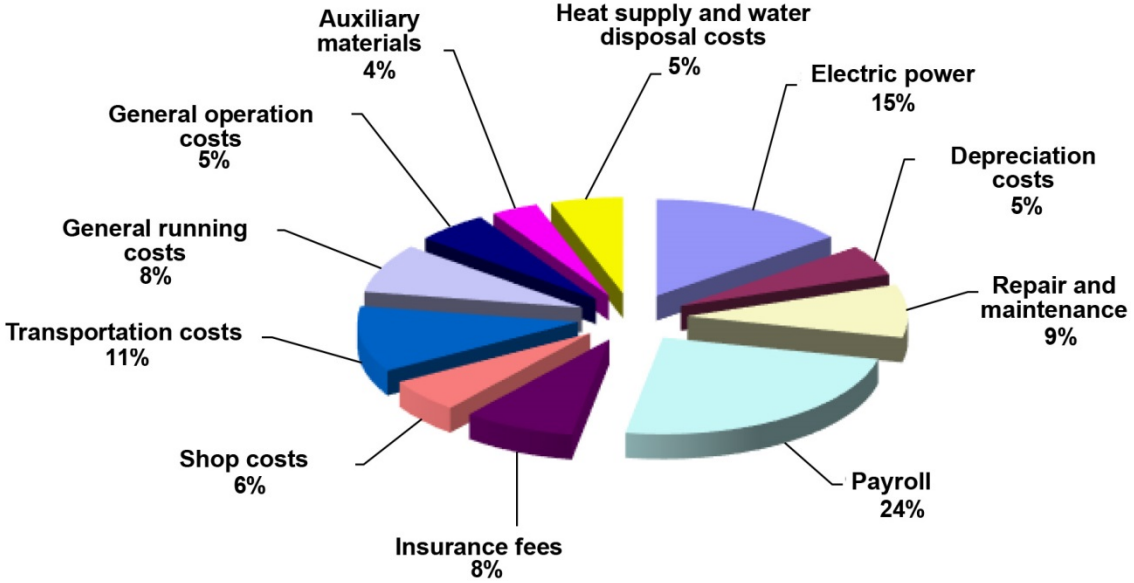
- **low foundation load:** counterrotation of rotors balances the engine operation, minimizes vibration and force impacts on the foundation;

- **low design and installation costs** because of small size and modular design of the unit with all auxiliary system. E.g., construction factor for a Kuban-.075 TG is equal to 2.2-2.4, for SRSE-100 construction factor is equal to 1.2-1.3.

UTILITIES COST STRUCTURE

The share of electric power cost in the structure of thermal energy production and transportation cost is 9.5%





The share of electric power cost in the structure of water hoisting and transportation cost is 15%

SRSEs INTRODUCTION IN INDUSTRIAL AND SERVICE BOILER ROOMS

Steam boilers of various types used in industrial and service boiler rooms produce steam at 12 to 40 atm. It is subsequently reduced through a pressure-reducing and desuperheating station (PRDS) to a working pressure equal to 1.0-7 atm., therefore the easiest and the most efficient solution for transforming boiler rooms into cogeneration plants is installation of low power steam turbine with an appropriate backpressure.

The choice of cycle arrangement and equipment for the creation of cogeneration plants is determined by the heat consumption behavior of the boiler rooms and their technical and economic performance: load diagrams, equipment characteristics, the level of presumable capital investments, etc.

A SRSE-1.0 power unit is installed in a boiler room on a PRDS bypass steam pipeline. It puts the steam pressure difference to good use for the production of electric energy; whereupon steam flow at the turbine outlet does not change and the steam is used for process need. The boilers steam flow is changed only insignificantly. A SRSE-1.0 power unit is placed in a boiler room; it does not require significant changes of the cycle diagram.

SRSEs INTRODUCTION AT THE EXISTING THERMAL POWER PLANTS (OR GTUs with HRSGs)

The introduction of SRSEs at existing thermal power plants (or GTUs with HRSGs) is a retrofitting and upgrade of the thermal power plant intermediate-pressure section with installation of one or two SRSE-based power units having a capacity up to 1000 kW in order to compensate some balance of plant electric power.

The installation of new equipment does not change the power plant thermal and electric energy output. The retrofitting and upgrade project does not touch upon structural and other infrastructural facility reliability and safety characteristics.

When SRSEs are introduced at thermal power plants, one or two SRSE-1.0 screw rotor steam engine are installed in parallel to the existing PRDS system between the main boiler outlet steam pipeline and the low pressure manifold. The SRSE inlet pipeline is tapped to the main gas turbine unit HRSGs outlet steam pipeline or to the heat extraction pipeline from the thermal power plant intermediate pressure cylinders. The project includes a pressure reducing station based on an electrically operated control valve for reducing the pressure of the steam fed to the SRSE to 16 bar. It is intended to install an attemperator for reducing the temperature of the steam fed to the SRSE. After cooling, steam is distributed between one or two SRSEs. Downstream of one or two SRSEs, steam is collected to a single pipeline tapped to the pipeline at the outlet of the existing PRDS and them distributed among steam consumers.

Electric energy produced by the SRSE generator is to be fed to the existing 10/6/0.4 kV balance of plant switchgear.

ENGINEERING RESTRICTIONS ON USE OF THE SRSEs

1. **SRSEs can be installed only on** those facilities that operate sufficiently powerful steam boilers and steam is produced on a permanent basis.

2. **The minimum steam flow** required for a SRSE operation amounts to 4.5 t/h, whereupon the engine operates virtually at idle, without generating electric energy (the SRSE parameter chart is shown in slide 9, the tabulated data are shown in slide 10).

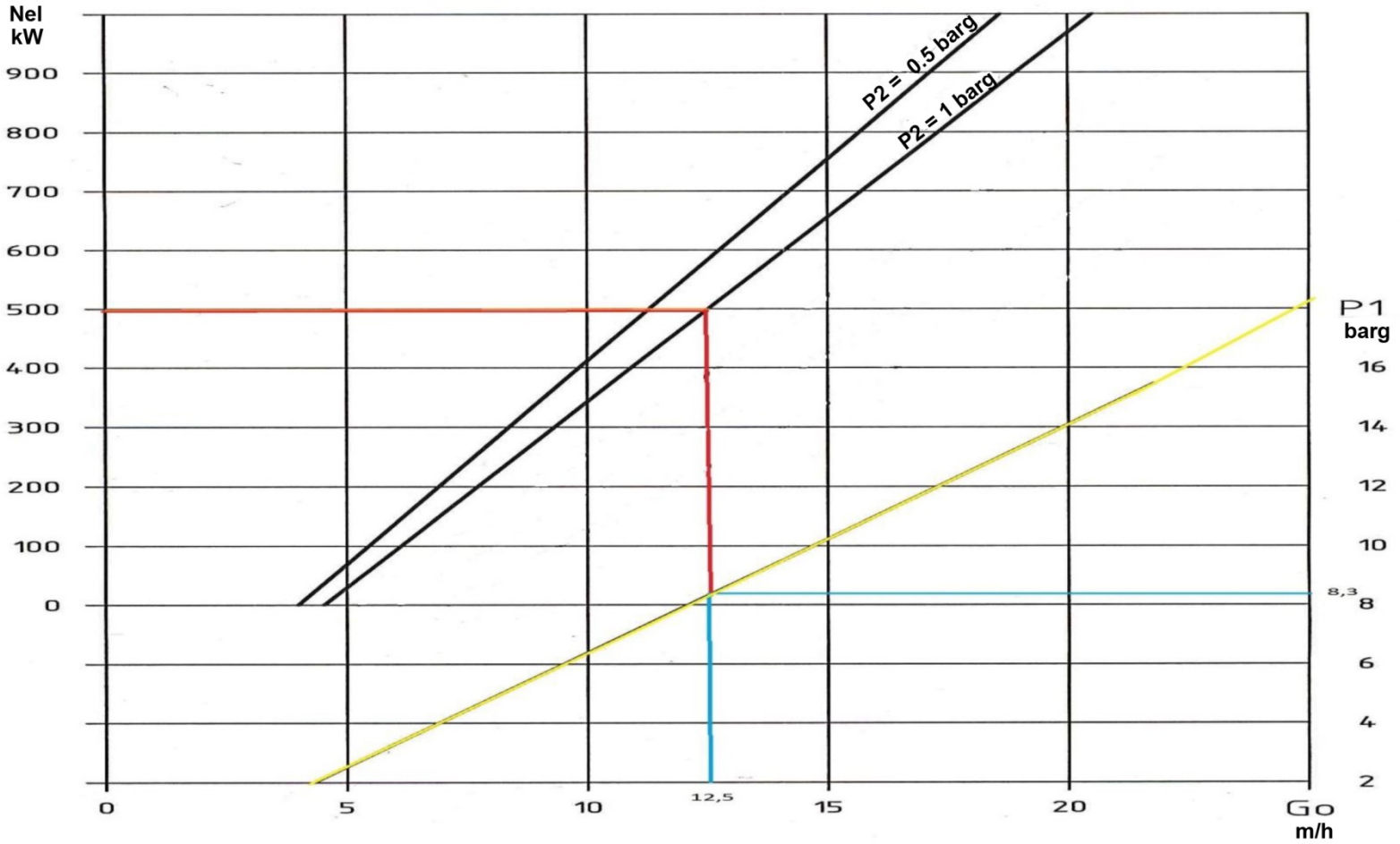
3. **To reach nominal rating,** a 500-kW SRSE needs at least 5 Gcal/h heat consumption (by the consumers connected to the boiler room). A 1000-kW one needs at least 9 Gcal/h heat consumption.

4. **SRSEs are used only** for auxiliary power supply, without generating mains power. The equivalent diagram of a SRSE network connection is shown in slide 11.

5. **The electric power produced by SRSEs** is rigidly linked to boiler operation parameters; it depends on seasonal boiler room loads.

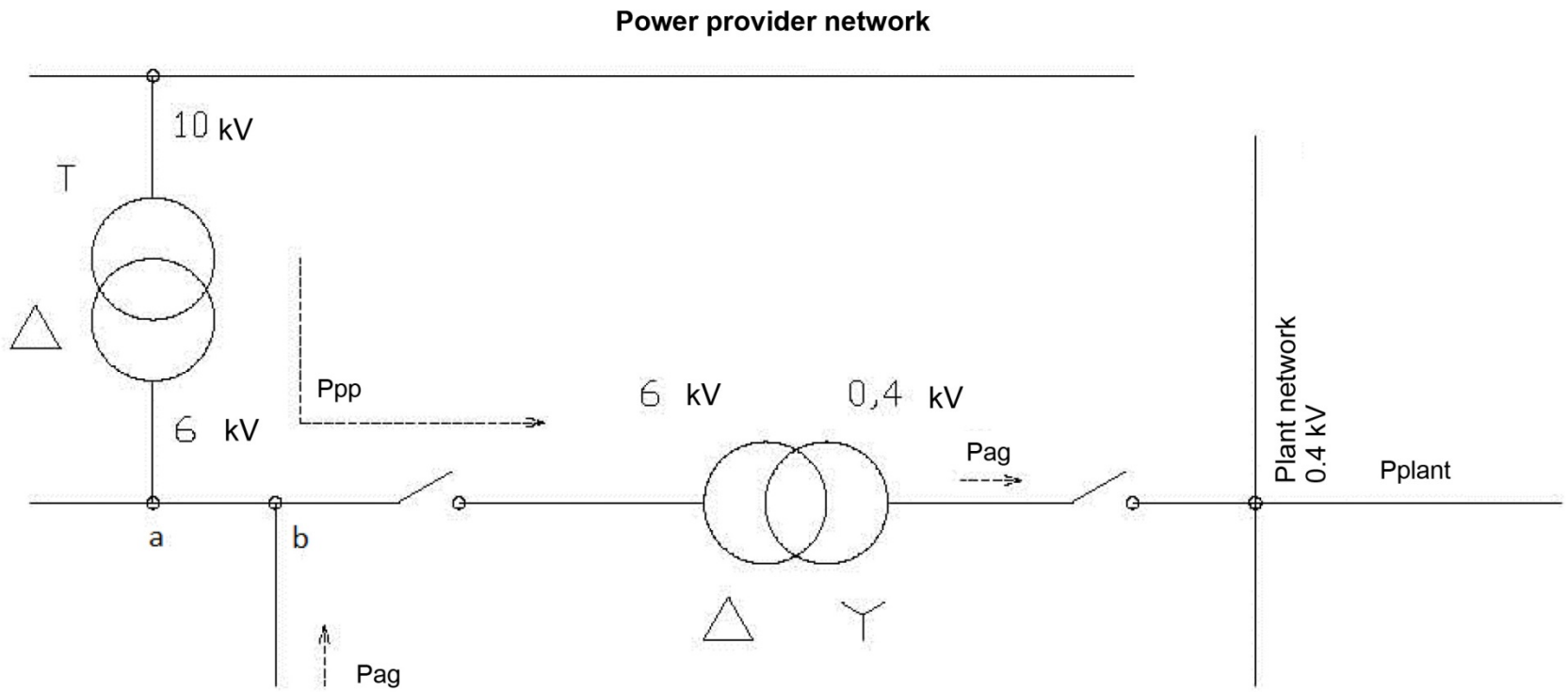
6. **The actual** SRSE operating factor amounts approximately 0.7 in normal mode of operation.

SRSE-1.0-АГ-315-3.5-60 PARAMEER CHART



SRSE PARAMETER CHART (TABLE)

Mode	SRSE Load, %	Steam Flow, t/h	Positive Steam Pressure at SRSE Inlet, bar	Counterpressure, bar (Positive)	Power Output, kW
1	20	7,5	5	1	220
2	30	9,5	6,3	1	300
3	50	14,5	9,5	1	500
4	70	16	10,8	1	700
5	100	20	14	1	1000



A power equivalent of a transformer is connected to point "a" for connecting the SRSE asynchronous generator (AG) with the plant (boiler room) network and the power supply organization network.

The AG is connected to point "b" via a vacuum circuit breaker.

The SRSE control system maintains the AG power (Pag) so that it would be close but less than the balance of plant power consumption (Pplant). Therefore, active power flow to the power supplying organization energy grid is impossible.

1 **The maximum economic benefit** and the minimum payback period can be obtained if SRSEs are introduced at household waste, timber processing industry and agricultural waste incineration plants. In this case, there is no fuel component in the cost of the energy produced by the SRSE (fuel is burned anyway, and the produced heat is discharged into the atmosphere). The cost of 1 kWh of power at such plants with large balance-of-plant power consumption can amount to less than 30 kopeks.

2 **The second most efficient option** is the introduction of SRSEs at boiler rooms with intermediate and high-power boilers (total steam capacity of running boilers at least 10 tons per hour) and a significant thermal energy output. The following factors mainly impact introduction efficiency:

- The cost of thermal energy produced by the boiler room;
- The cost of purchased electric energy;
- Electric energy consumption.

The approximate cost of 1kWh at such facilities may vary from 65 kopeks to 1 ruble.

3 **Using SRSEs** at electric power plants can be efficient as well because at present power generating enterprises have to purchase balance-of-plant electric energy at the electricity market.

SRSE MODEL RANGE

Name	SRSE-150	SRSE-500	SRSE-800	SRSE-1000
Operating medium	water steam	water steam	water steam	water steam
Inlet steam pressure, MPa (a)	0,5- 0,7	0,7 – 1,4	0,8 – 1,4	0,8 – 1,4
Inlet steam temperature, °C	up to 200	up to 200	up to 200	up to 200
Outlet steam pressure, MPa (a)	0,05-0,1	0,05-0,1	0,05-0,1	0,05-0,1
Steam flow, t/h	8-10	8– 14	16– 20	18 – 25
Maximum el. power, kW	250	500	800	1000
Voltage, kV	0,4	0,4; 6,3; 10,5	0,4; 6,3; 10,5	0,4; 6,3; 10,5
Voltage adjustment range, %	15-100	10 – 100	10 – 100	10 - 100
Frequency, Hz	50	50	50	50
Unit (turbine) weight, maximum, kg	3500	3500	3500	3500
Unit (turbine) dimensions, l*w*h, mm	2420*1300*1440	2420*1300*1440	2420*1300*1440	2420*1300*1440
Specified life, years	25	25	25	25

CAPITAL COSTS (for a SRSE-100 machine)		
Name	Meas. Unit	Total, rub. (approximately)
Design	set	2 000 000
Equipment	set	33 000 000
Construction and installation works, commissioning works (with allowance for the cost of materials)	set	15 000 000
TOTAL:		**50 000 000**

RUNNING COSTS (for a SRSE-100 machine)			
Name	Meas. Unit	Quantity	Total, rub. (approximately)
Surcharge paid to the boiler room personnel for servicing the unit (approximately, annually)	rate	1	350 000
Routine repair work (annually)	set	1	500 000
Overhaul (triennially)	set	1	1 650 000

CLCULATION OF COST OF THE ELECTRIC ENERGY PRODUCED BY A SRSE

Actual fuel cost data and consumed electric energy volume data are needed to calculate the cost price of generated electric energy and to assess the SRSEs introduction projects payoff time.

Let us consider a boiler room from the Moscow Region as an example (2014 data):

- Cost of 1 thous. cbm natural gas: 4,975.07 rub.;
- Annual electric energy consumption: 4 711 216 kWh;
- Presumed electric energy generation by SRSEs (90% of total consumption): 4,240,000 kWh;
- Electricity rate: 3.82 rub./kWh.

Fuel component in the cost of 1 kWh:

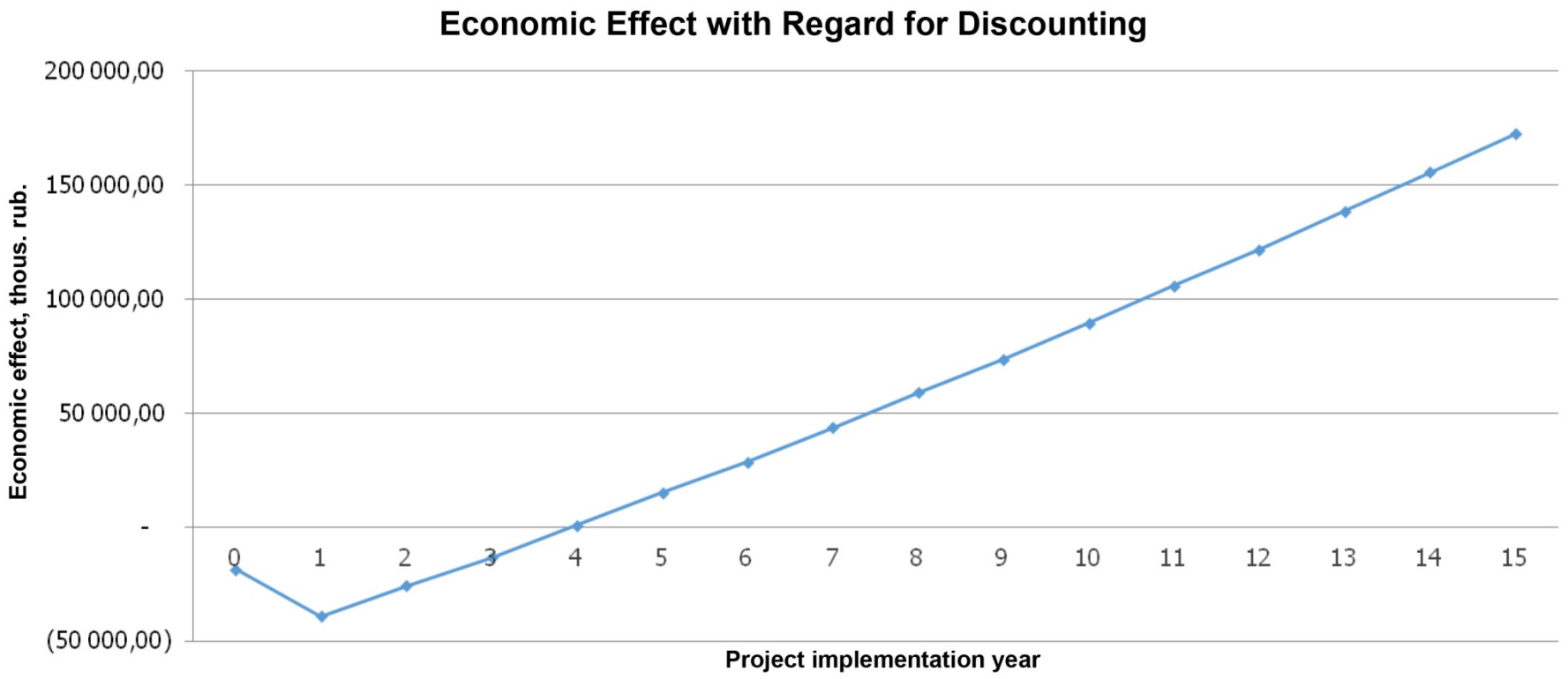
- In natural terms: 135 grams of equivalent fuel for production of 1 kWh;
- Equivalent fuel to natural one (natural gas) conversion factor: c=1.2
- Fuel component in monetary terms: 0.000135/1,2 * 4975.07=0,56 rub./kWh.

Repair and operation components in the cost of 1 kWh:

- Salary component: 350 000 / 4 240 000 = 0,082 rub.
- Routine repair work: 500,000 / 4 240 000 = 0.118 rub.
- Overhaul (normalized to one year): 1,650,000 / 3 / 4,240,000 = 0.13 rub.

TOTAL COST OF POWER GENERATION BY SRSE - 1 kWh costs 0.89 rub.

The estimation calculation of economic effect of the SRSE introduction is shown in Slide 17.
We use the current CB refinancing rate as the discounting rate.
The payback period without regard for discounting will amount to 2.5 years.
The payback period without regard for discounting will amount to 3.5 years.



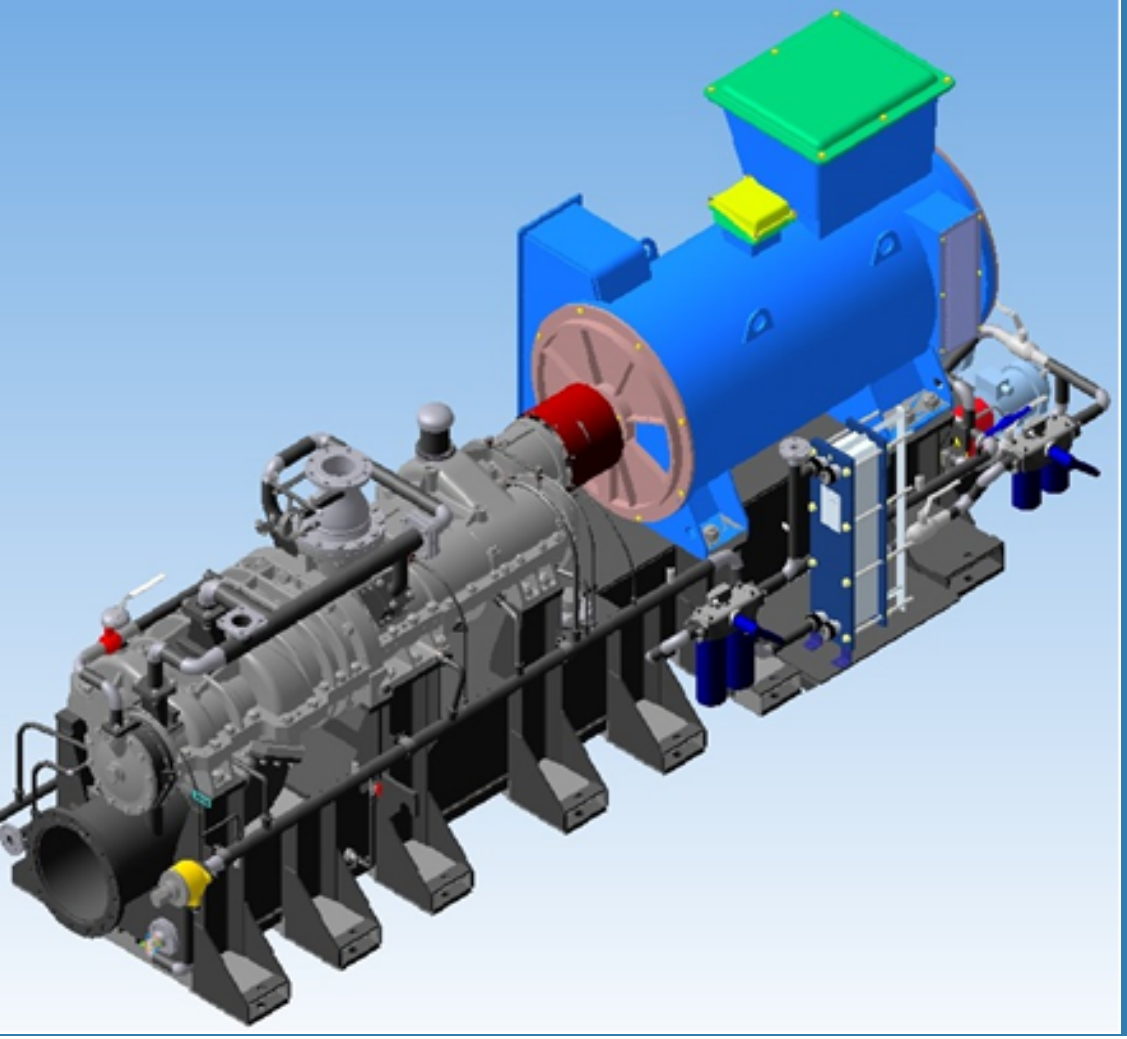
Calendar year	Project implementation year	Forecasted deflator indexes (as compared to 2015).	Purchase electricity rate (annual increase by 15%), rub./thous. kWh	Electricity produced by the SRSE, thous. kWh	Savings on electricity purchases, thous. rub.	Proprietary electricity generation costs, thous. rub					Investment costs of SRSE introduction (IC), thous. rub.	Changes in cash flows, thous. rub.		Annual effect, thous. rub.	Cumulative introduction annual effect, thous. rub.	Discounting factor	Discounted annual effect, thous. rub.	Cumulative discounted introduction effect, thous. rub.	Discouting rate
						Total	Including:					-IC	Changes in cash flows, thous. rub.						
							Fuel component:	payroll:	Routine repairs	Overhauls									
2015	0	100,00%	3820,00	-	-	-	-	-	-	-	18 500,00	- 18 500,00	-	- 18 500,00	- 18 500,00	1	- 18 500,00	- 18 500,00	14%
2016	1	110,30%	4393,00	2 120,00	9 313,16	1 502,51	1 309,48	193,03	-	-	31 500,00	- 31 500,00	7 810,65	- 23 689,35	- 42 189,35	0,88	- 20 780,13	- 39 280,13	14%
2017	2	120,20%	5051,95	4 240,00	21 420,27	3 875,73	2 854,03	420,70	601,00	-	-	-	17 544,54	17 544,54	- 24 644,81	0,77	13 499,95	- 25 780,18	14%
2018	3	131,00%	5809,74	4 240,00	24 633,31	6 385,46	3 110,46	458,50	655,00	2 162	-	-	18 247,84	18 247,84	- 6 396,96	0,67	12 316,78	- 13 463,40	14%
2019	4	140,30%	6681,20	4 240,00	28 328,30	4 523,83	3 331,28	491,05	701,50	-	-	-	23 804,47	23 804,47	17 407,51	0,59	14 094,16	630,76	14%
2020	5	149,80%	7683,38	4 240,00	32 577,55	4 830,15	3 556,85	524,30	749,00	-	-	-	27 747,40	27 747,40	45 154,91	0,52	14 411,13	15 041,89	14%
2021	6	159,90%	8835,89	4 240,00	37 464,18	7 794,17	3 796,67	559,65	799,50	2 638	-	-	29 670,02	29 670,02	74 824,92	0,46	13 517,26	28 559,15	14%
2022	7	170,40%	10161,28	4 240,00	43 083,81	5 494,38	4 045,98	596,40	852,00	-	-	-	37 589,43	37 589,43	112 414,36	0,40	15 022,14	43 581,29	14%
2023	8	179,90%	11685,47	4 240,00	49 546,38	5 800,70	4 271,55	629,65	899,50	-	-	-	43 745,69	43 745,69	156 160,04	0,35	15 335,45	58 916,73	14%
2024	9	189,10%	13438,29	4 240,00	56 978,34	9 217,49	4 489,99	661,85	945,50	3 120	-	-	47 760,85	47 760,85	203 920,89	0,31	14 686,84	73 603,57	14%
2025	10	197,00%	15454,03	4 240,00	65 525,09	6 352,07	4 677,57	689,50	985,00	-	-	-	59 173,02	59 173,02	263 093,91	0,27	15 961,56	89 565,13	14%
2026	11	203,60%	17772,14	4 240,00	75 353,85	6 564,88	4 834,28	712,60	1 018,00	-	-	-	68 788,97	68 788,97	331 882,89	0,24	16 276,67	105 841,80	14%
2027	12	210,50%	20437,96	4 240,00	86 656,93	10 260,61	4 998,11	736,75	1 052,50	3 473	-	-	76 396,32	76 396,32	408 279,21	0,21	15 856,75	121 698,55	14%
2028	13	217,10%	23503,65	4 240,00	99 655,47	7 000,17	5 154,82	759,85	1 085,50	-	-	-	92 655,30	92 655,30	500 934,50	0,18	16 869,69	138 568,24	14%
2029	14	223,60%	27029,20	4 240,00	114 603,79	7 209,76	5 309,16	782,60	1 118,00	-	-	-	107 394,03	107 394,03	608 328,54	0,16	17 151,90	155 720,14	14%
2030	15	230,20%	31083,58	4 240,00	131 794,36	11 220,87	5 465,87	805,70	1 151,00	3 798	-	-	120 573,49	120 573,49	728 902,03	0,14	16 891,92	172 612,06	14%

Possible scales of this power saving technology utilization are large enough. About 80,000 steam boiler rooms are operated in Russia. Those boiler rooms are usually used for production and heating purposes. They belong to enterprises of the housing and utility sector, sawmilling, food, paper, textile, metallurgy and many other industries.

SRSE as a steam engine within the 250-1000 kW power range, the SRSE has significant technical advantages over the steam turbine in respect of efficiency, dimensions, cost, reliability and safety.

A single basic model of an engine is used for various steam conditions determining the generating plant power with appropriate adjustment for the Customer's specific conditions. This fact permits to perform estimate calculations of introduction cost and economic efficiency of this technology efficiently enough.

The introduction of SRSEs at boiler rooms may produce a significant social effect: electric power production on own account permits one to "freeze" thermal energy rates in proportion to their electric power component (or even to reduce rates by this amount).



LLC «VT Technology»

THANK YOU FOR YOUR TIME!

wintoo

Russia , 191186 , St. Petersburg
Nevsky Prospect , d.30 , of.4.8
tel. / fax : (812) 571-90-90
(812) 315-79-02
www.wintoo.ru
info@wintoo.ru