Complex Tests of Half-Wave Transmission System and Introduction of Half-Wave Technology in the Near Future in Russia

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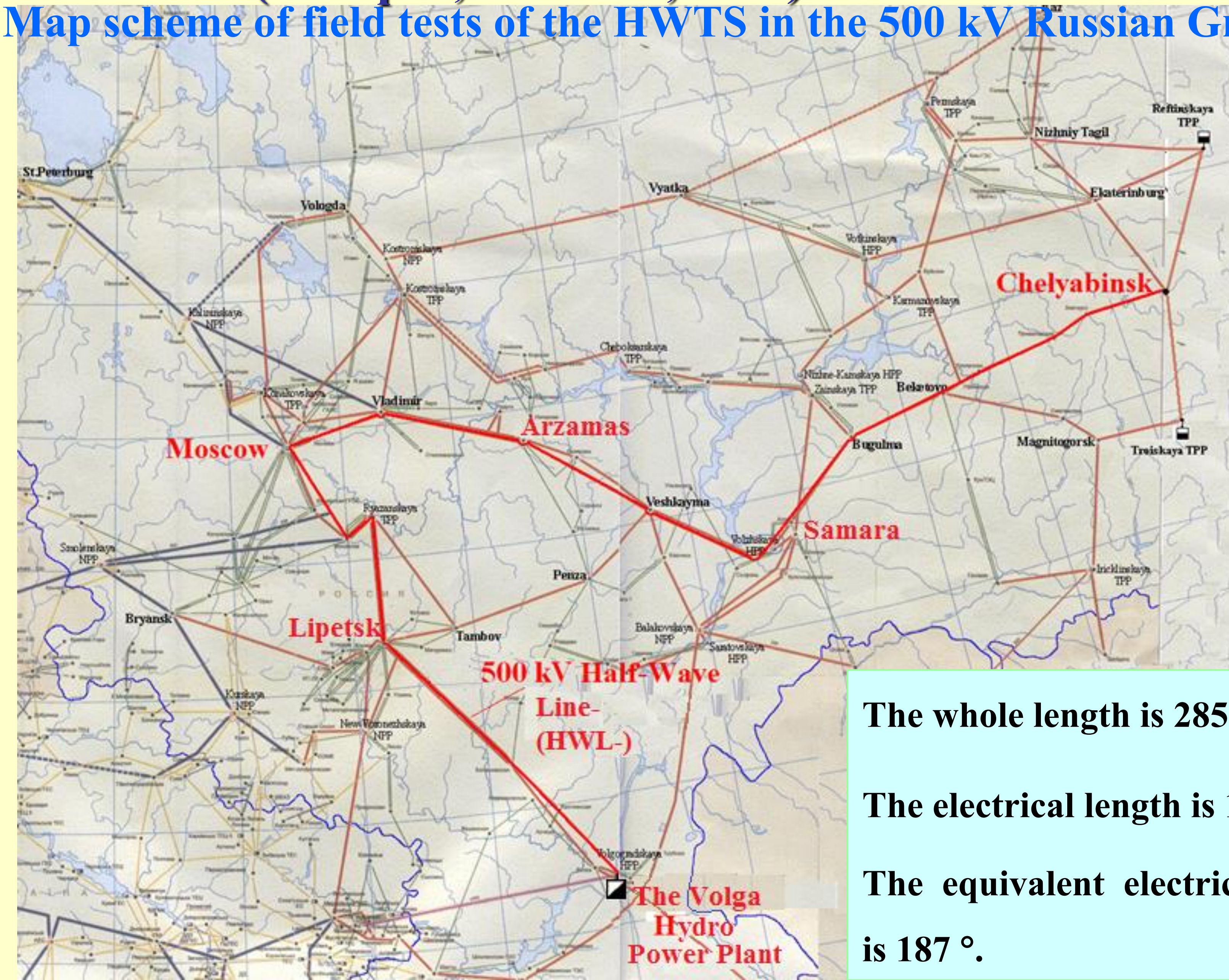
2013 Brazilian Seminar: Transmission Line with a little more than Half Wavelength

Part 1. Complex Tests of Half-Wave Transmission System (on April, 2nd and 9, 1967)

Map scheme of field tests of the HWTS in the 500 kV Russian Grid

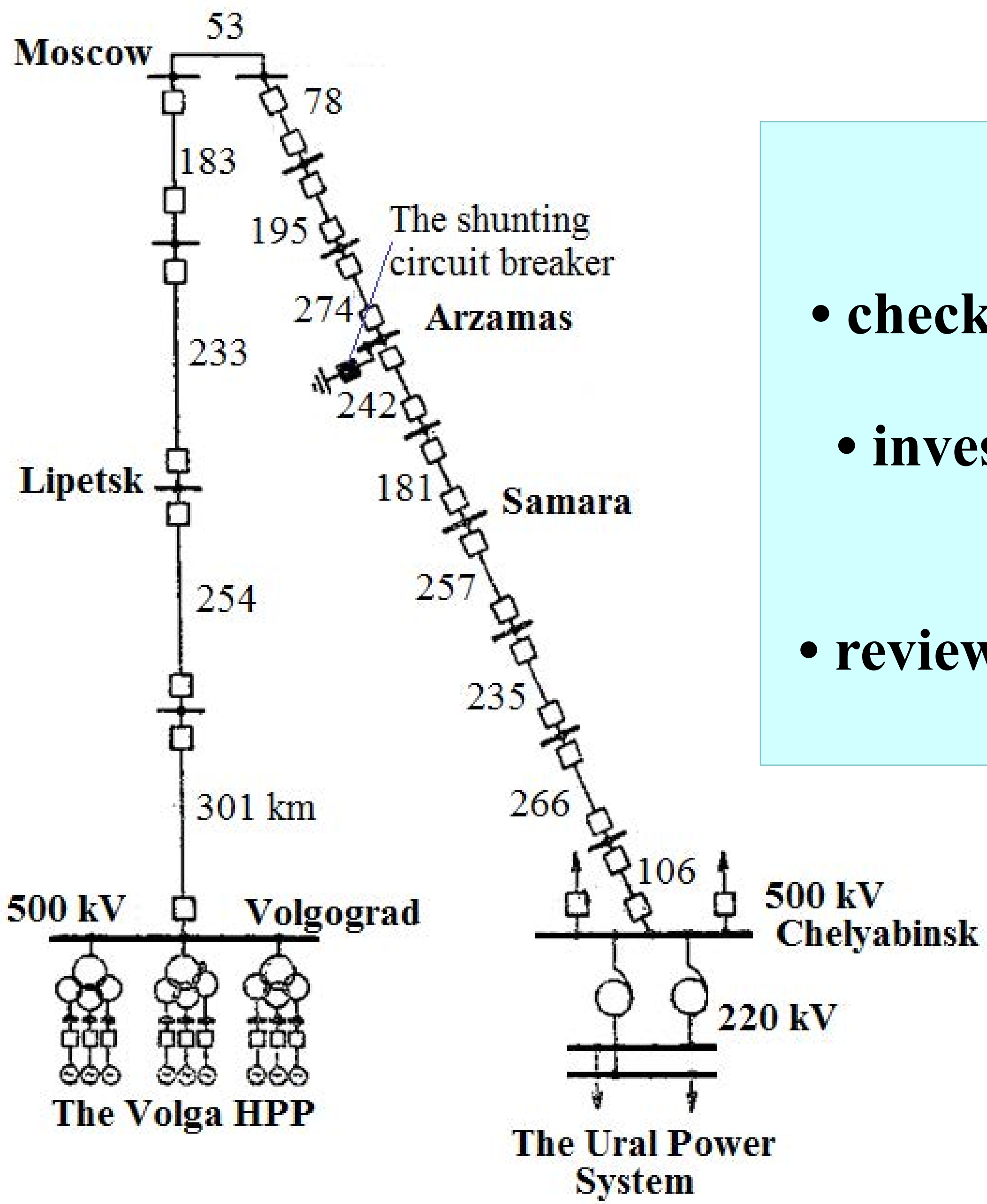


The whole length is 2858 km.

The electrical length is 173 °.

The equivalent electrical length is 187 °.

Connection Scheme of 500 kV Lines for tests of HWTS

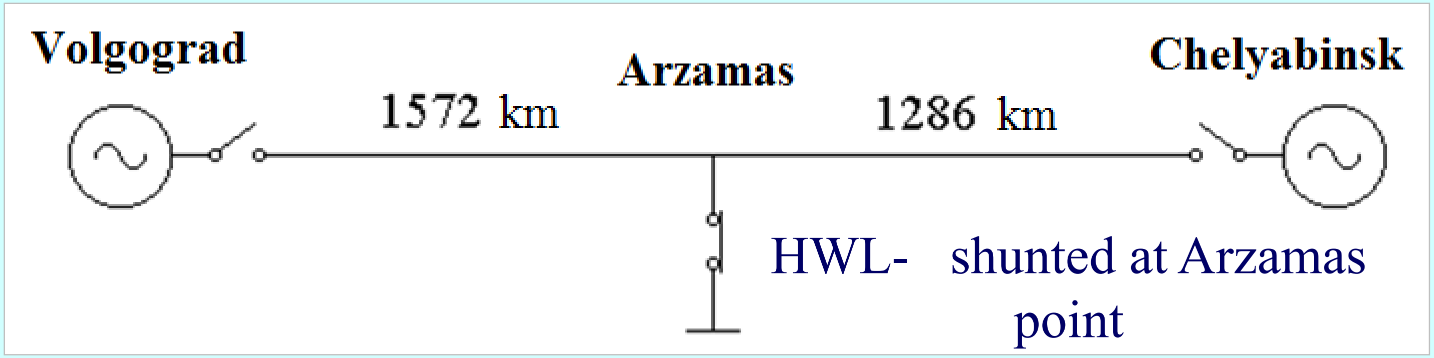


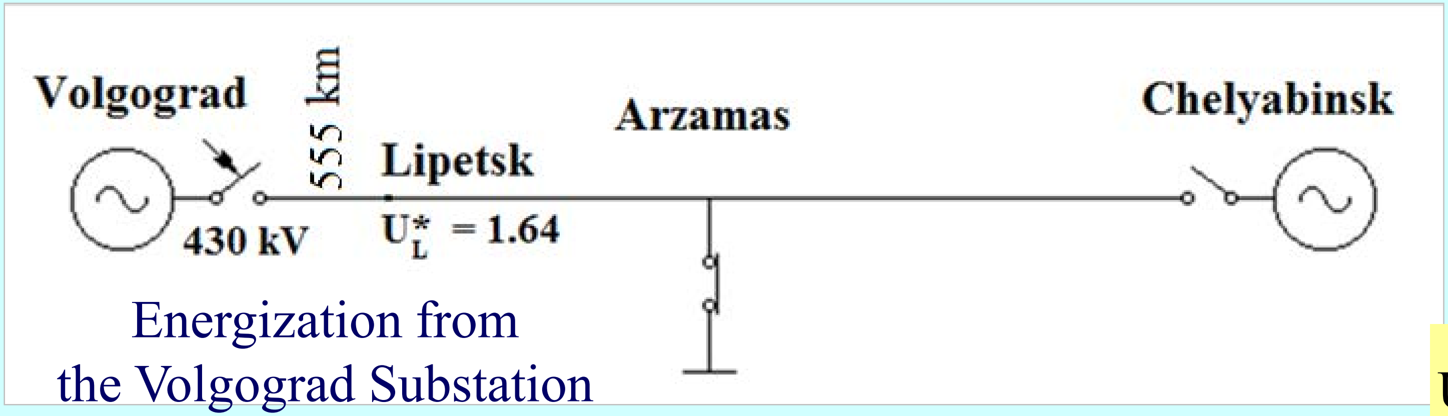
Purposes of the tests:

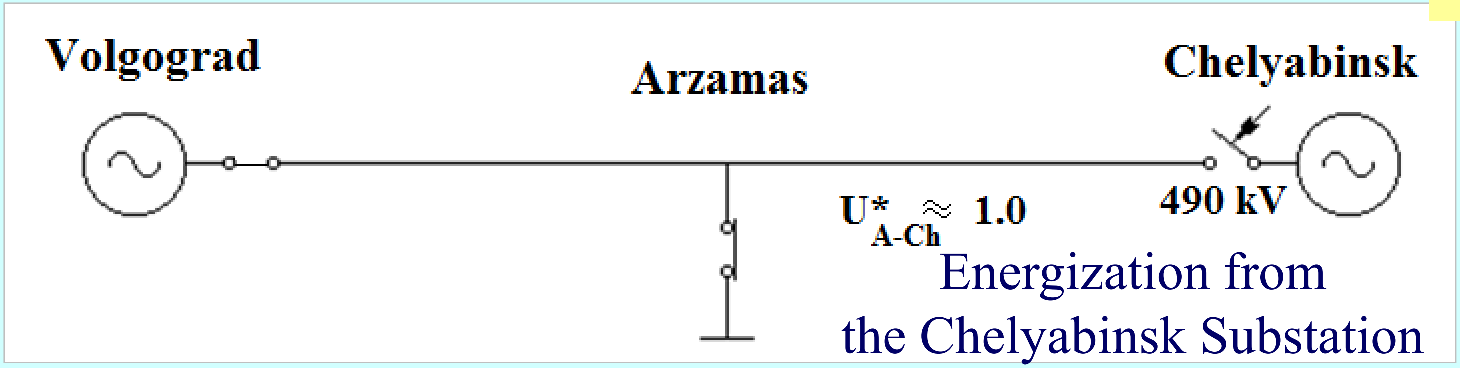
- check of loading characteristics;
- investigation of self-oscillation and its liquidation;
- review of the transients leading to overvoltages.

1. Energization and Synchronization Tests of HWTS

1.1 Energization of HWL- shunted at the middle part



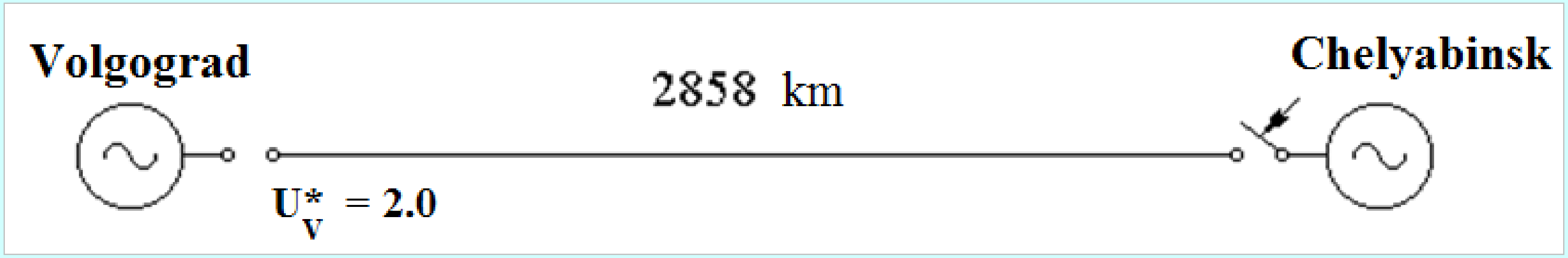




$U^* = \dfrac{U}{U_{ph.max}}$ is voltage in the per-unit system

$U_{ph.max} = \dfrac{525}{\sqrt{3}}\sqrt{2}$ is maximum phase operating voltage

1.2 Energization of open-ended HWL-

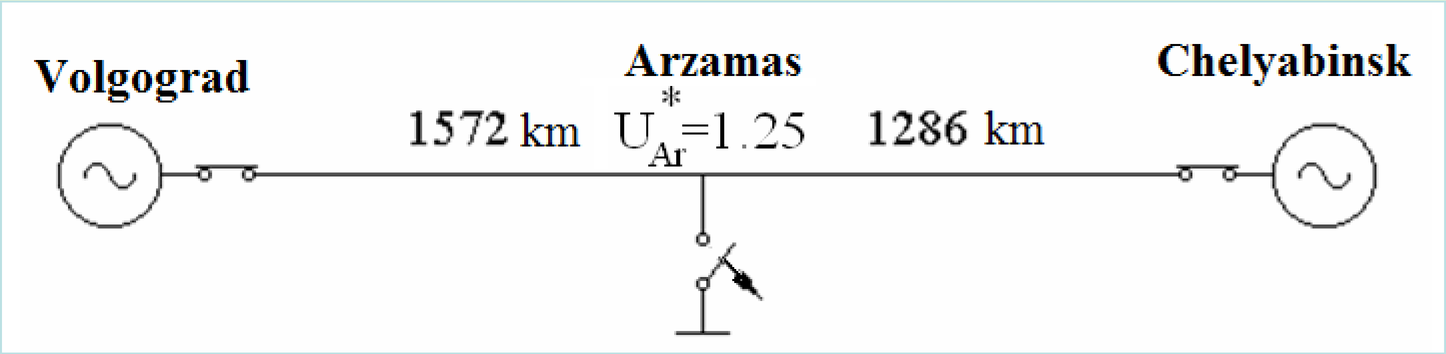


Switching-in from the Chelyabinsk Substation

Switching-in from the Volgograd Substation

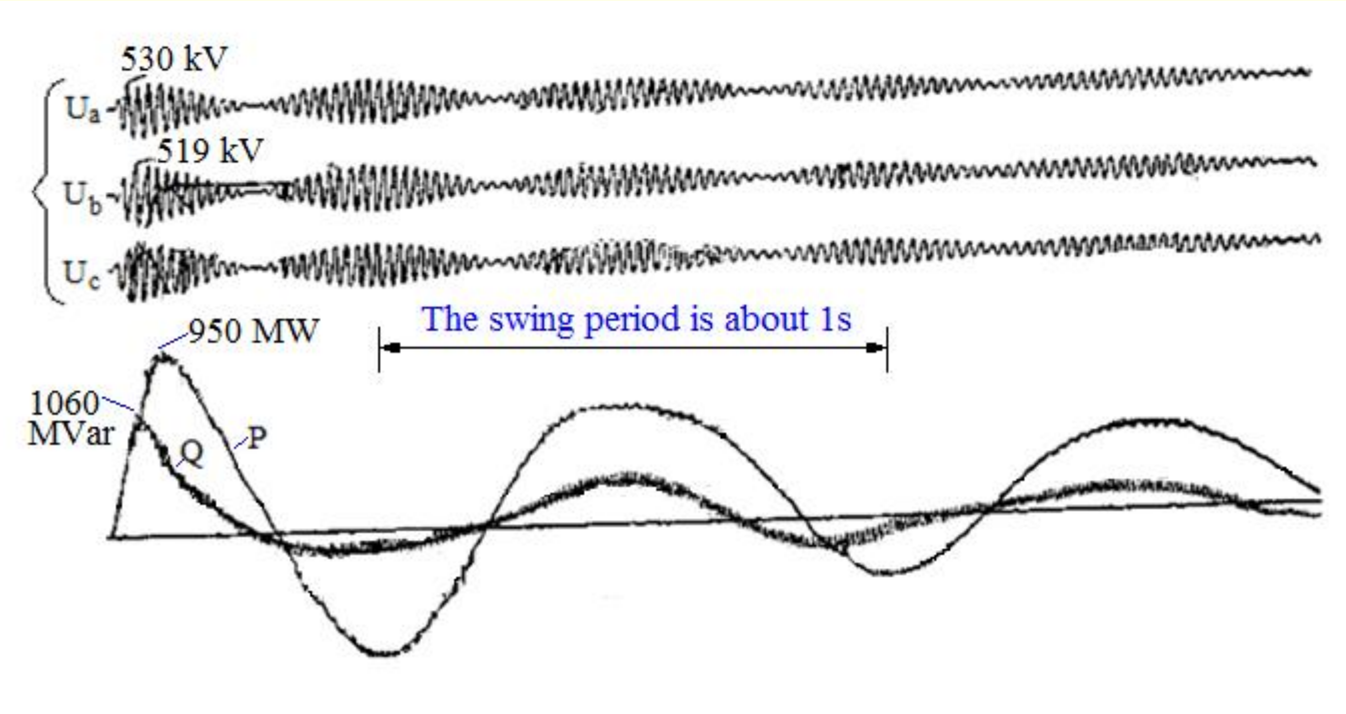
Opening of not loaded HWL-

1.3 Current Synchronization



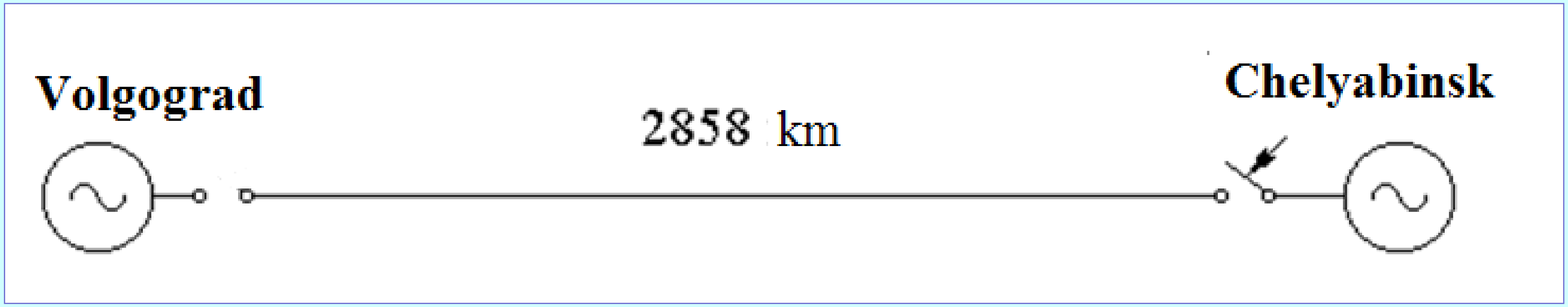
Voltage at the Arzamas point

Active and Reactive Power at the Volgograd Substation

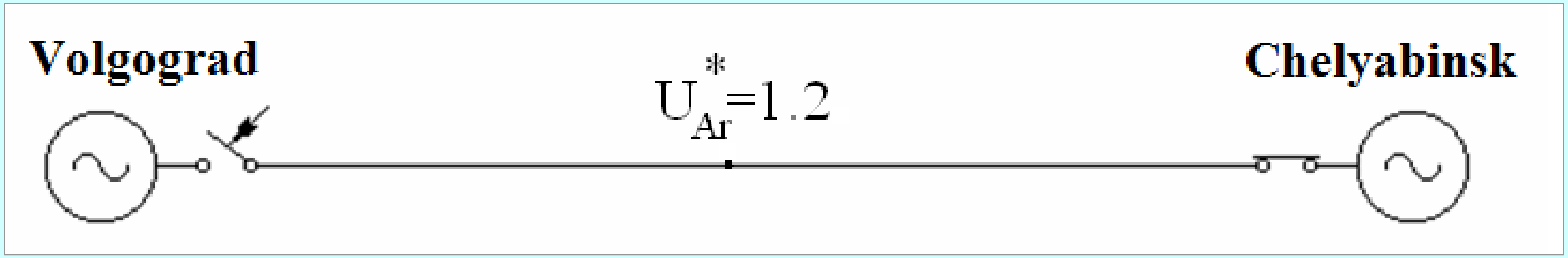


Data of current synchronization:
Frequency difference was 0.175 Hz;
Current in the shunt circuit breaker was 630 A.

1.4 Usual Synchronization

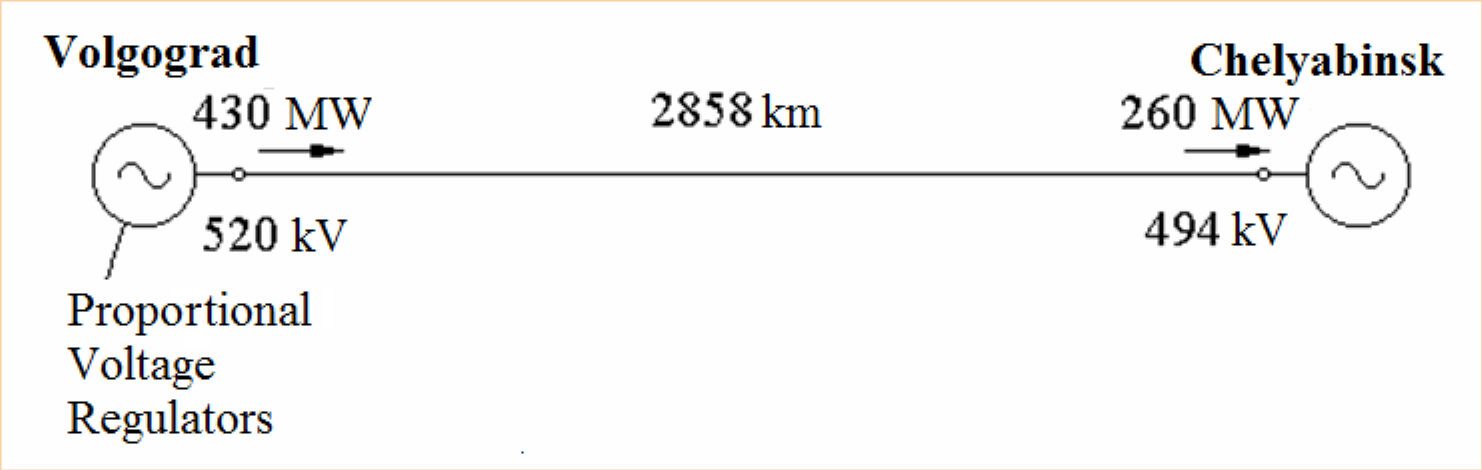


Energization of open-ended HWL-

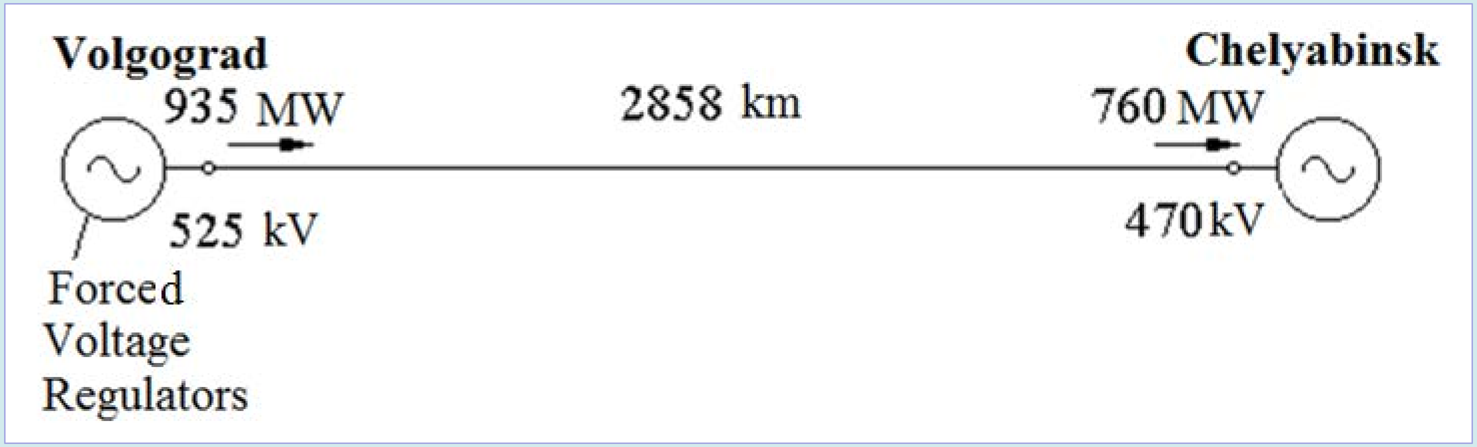


Synchronization at the Volgograd Substation

2. Tests of active power transfer

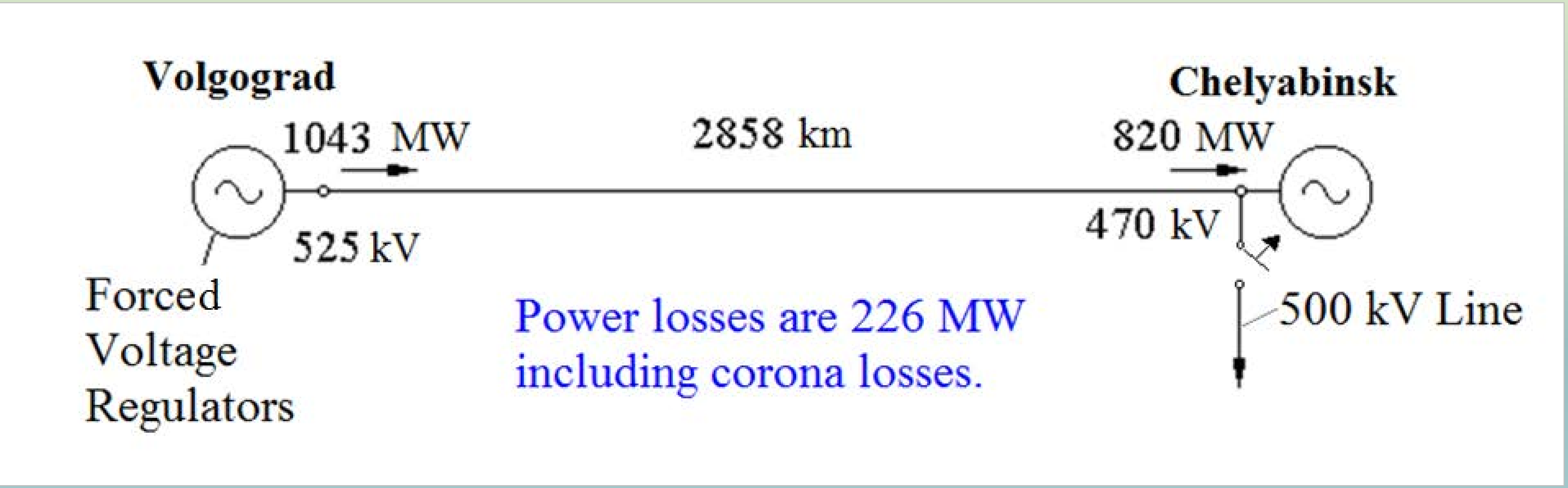


First marks of self-oscilation



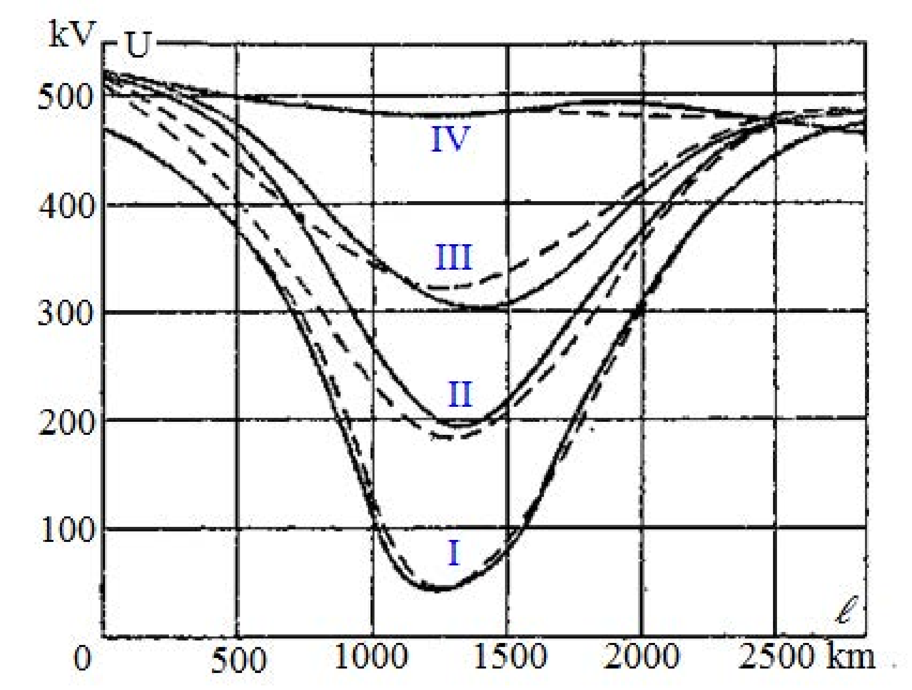
Operation without self-oscilation

Transfer of maximum active power

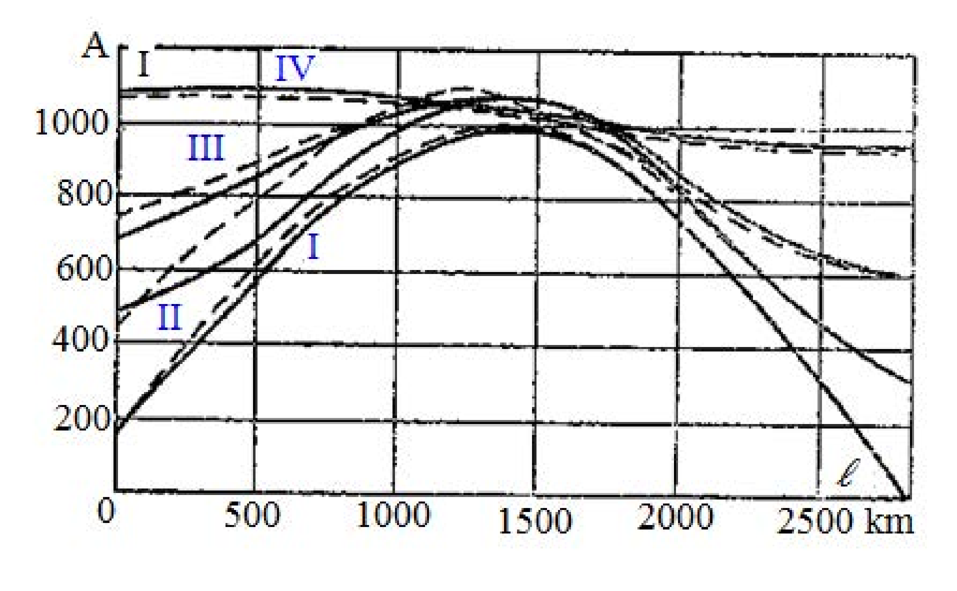


Natural power at voltage 525 kV is equal about 1000 MW.

Comparison of experimental and calculated data



Allocation of voltage



Allocation of current

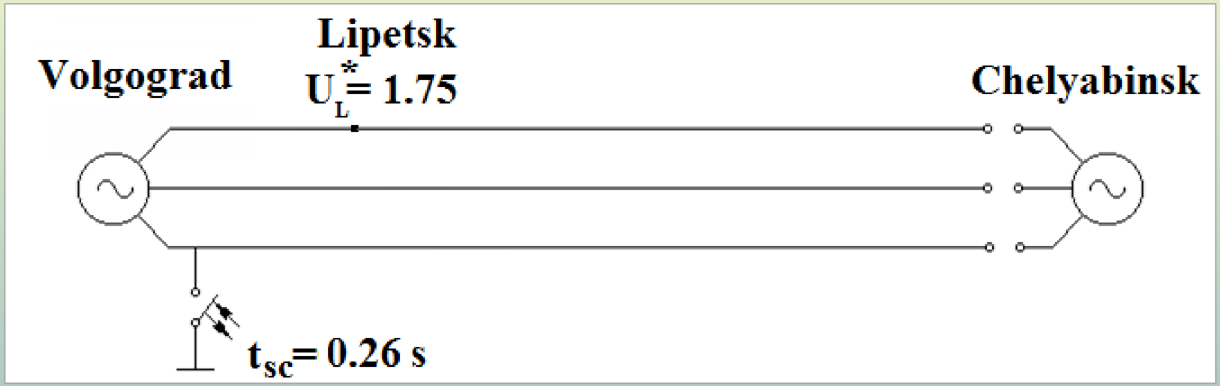
I - 100 MW
II - 400 MW
III - 650 MW
IV - 985 MW

——————— - test data

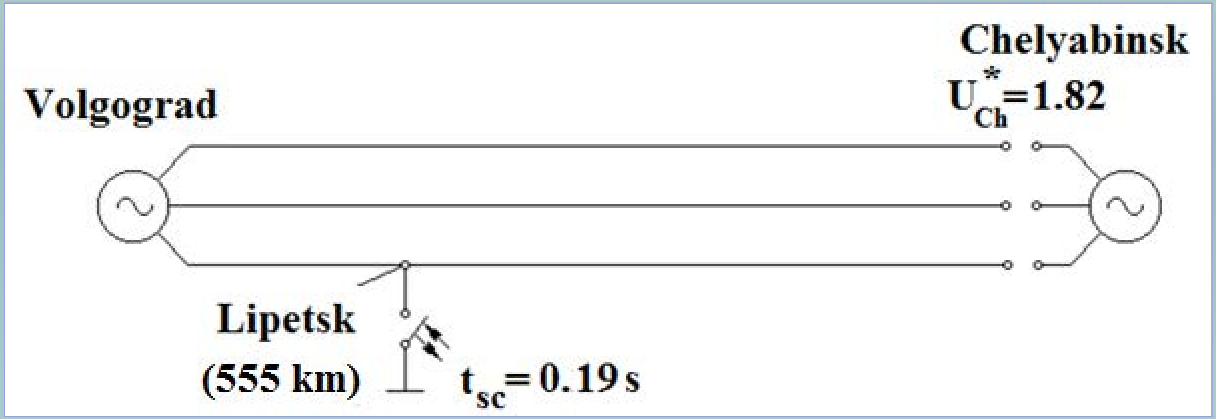
- — — — — - calculation

3. Tests of single phase short circuit under no-load and load conditions

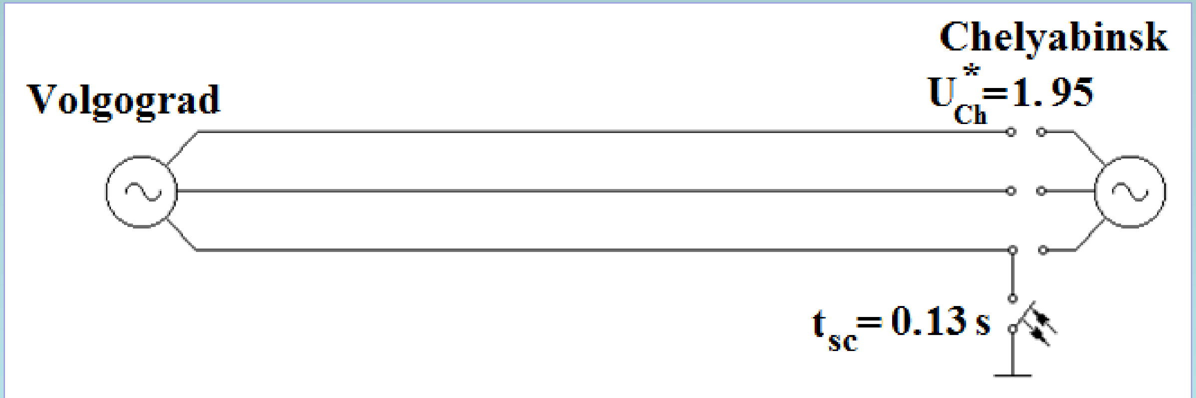
3.1 Tests of single-phase short circuit under no-load conditions



Single-phase short circuit at the Volgograd Substation



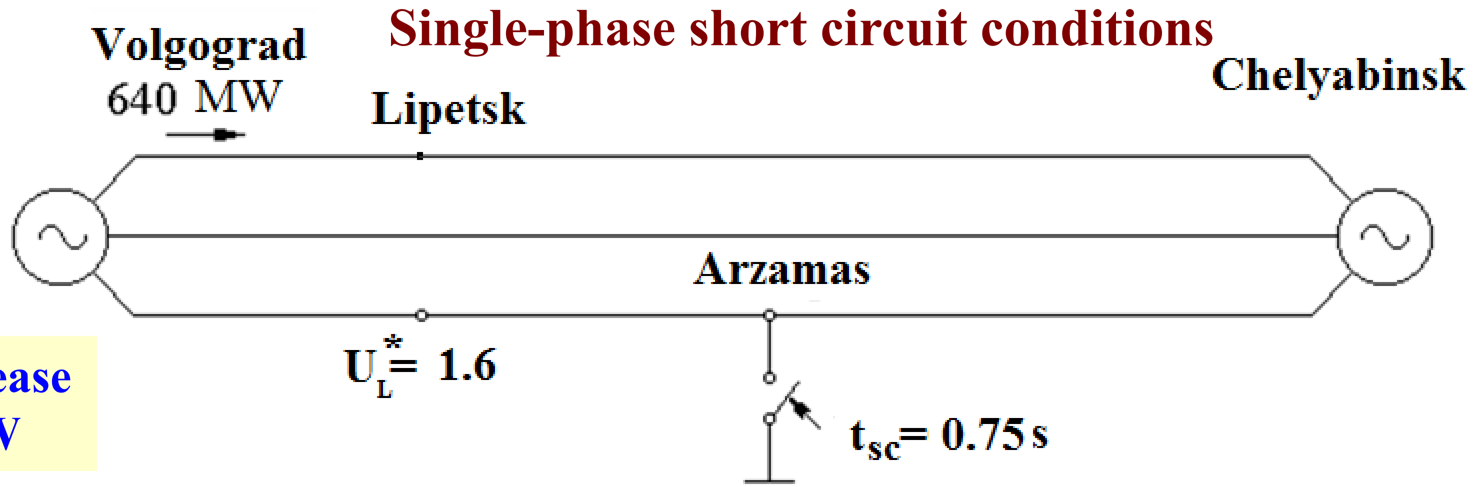
Single-phase short circuit at the Lipetsk Point



Single-phase short circuit at the Chelyabinsk Substation

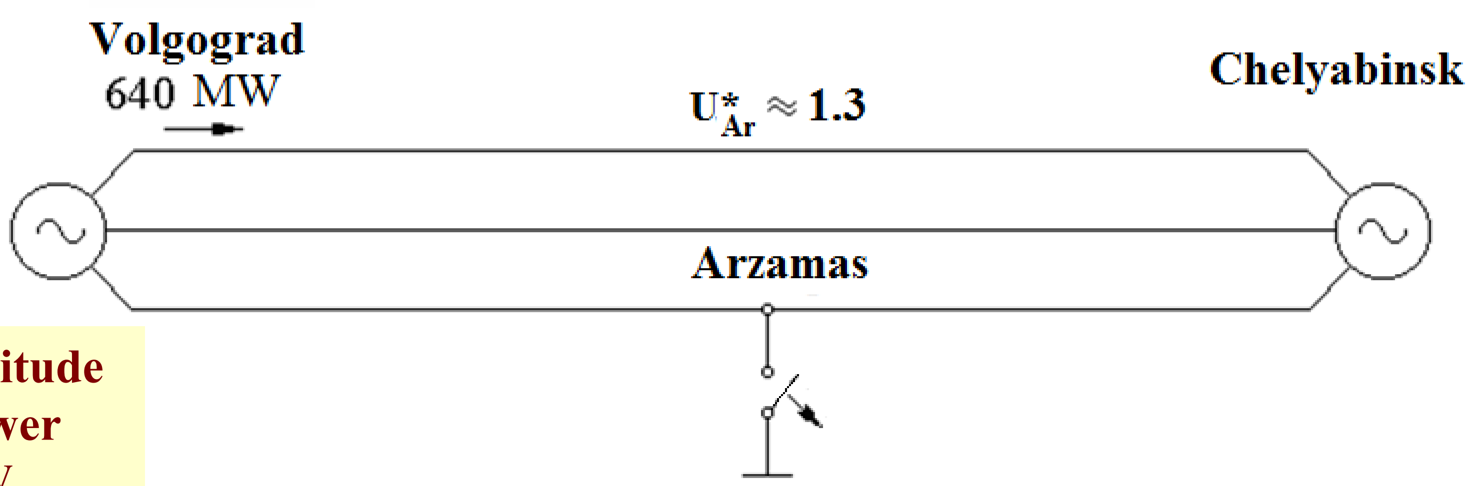
3.2 Test of single-phase short circuit at Arzamas under load conditions

Single-phase short circuit conditions



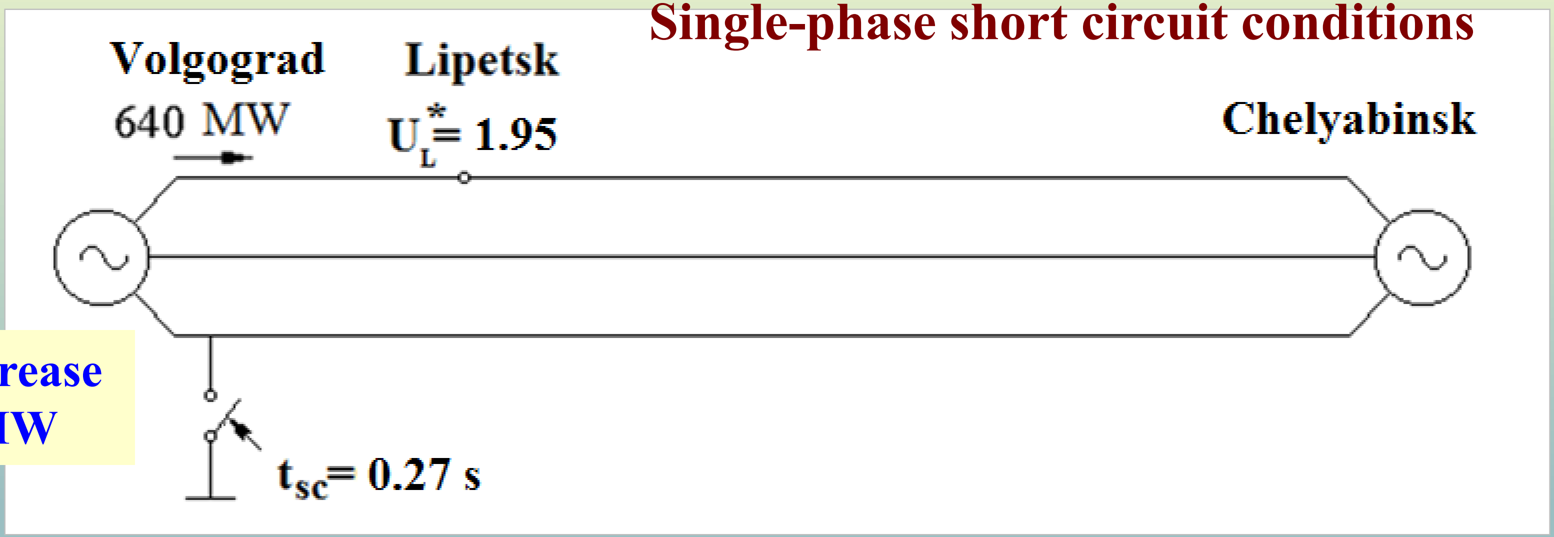
Power decrease ≈ 200 MW

Swing conditions

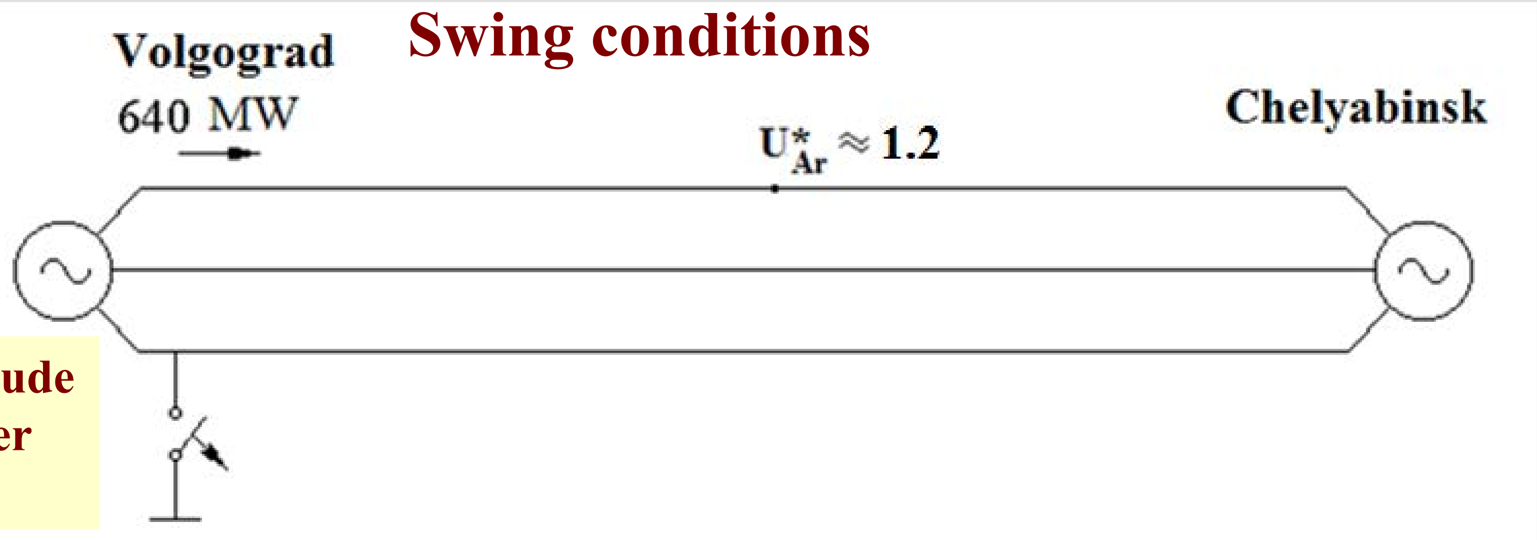


The first amplitude of active power ≈ 990 MW

3.3 Test of single-phase short circuit at Volgograd under load conditions

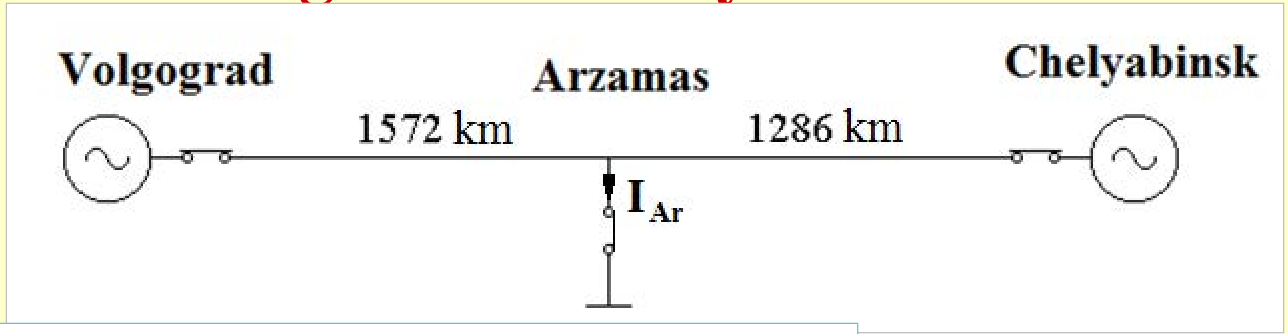


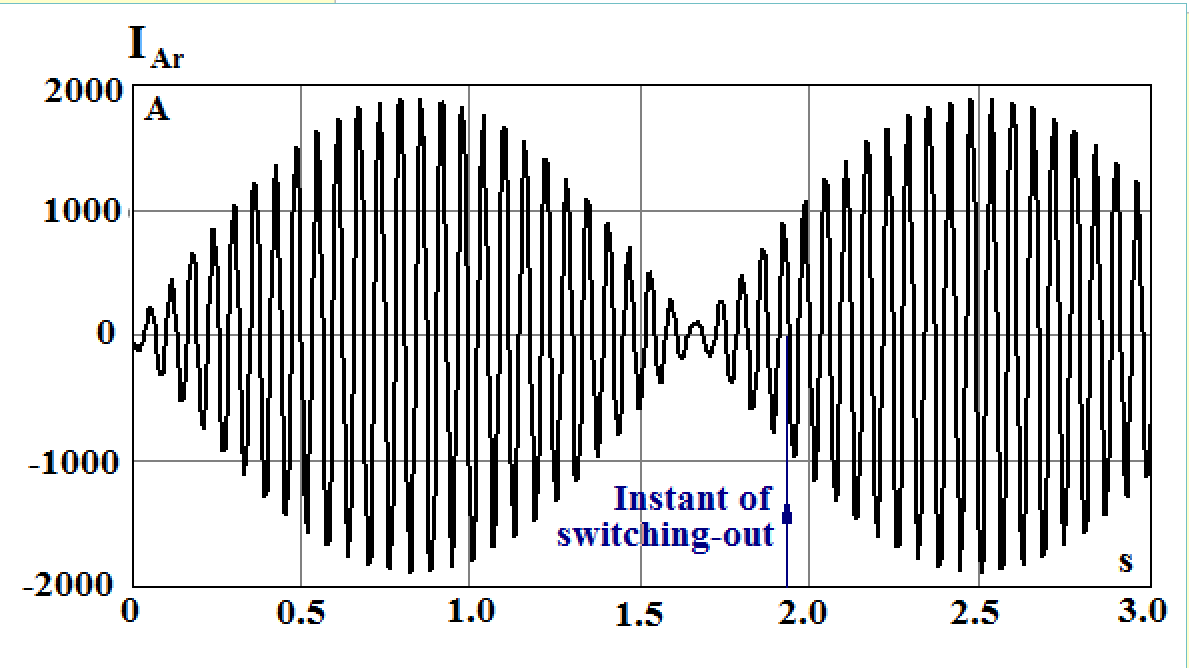
Power decrease ≈ 200 MW



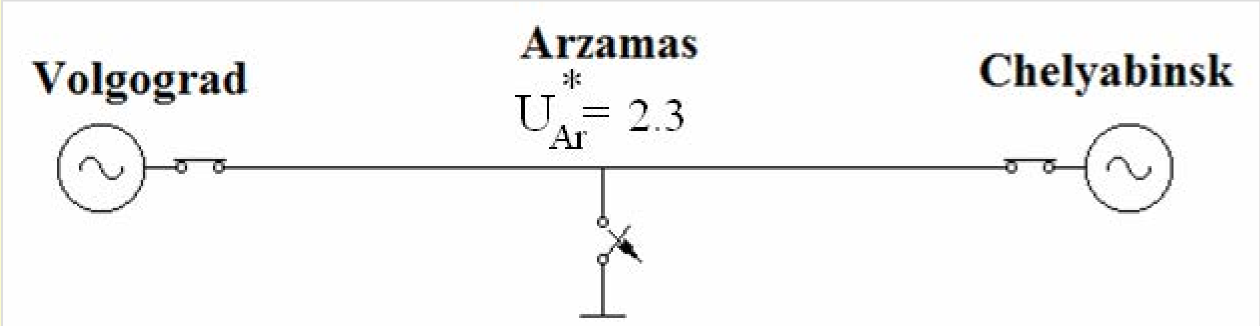
The first amplitude of active power ≈ 850 MW

4. Rough Current Synchronization





Data of rough current synchronization:
Frequency difference was 0.6 Hz;
Current in the shunting circuit breaker was 1020 A.



Conclusions to the part 1

1. The planned test program of HWTS Volgograd – Moscow – Chelyabinsk was successfully and completely executed. It was not observed difficulties in operation of the 500 kV commercial equipment.

2. Tests confirmed theoretical conclusions that HWTSs are efficient and can serve as means of energy transfer over very long distances.

3. Results of field tests have great value for the further development of the HWTS theory. The phenomenon of parametric instability of generators (self-oscillation) was investigated.

4. Ways of energization and synchronization of HWTS were tested. Results of tests showed, that these modes passed successfully without special measures of damping of swings and restrictions of internal overvoltages.

Conclusions to the part 1

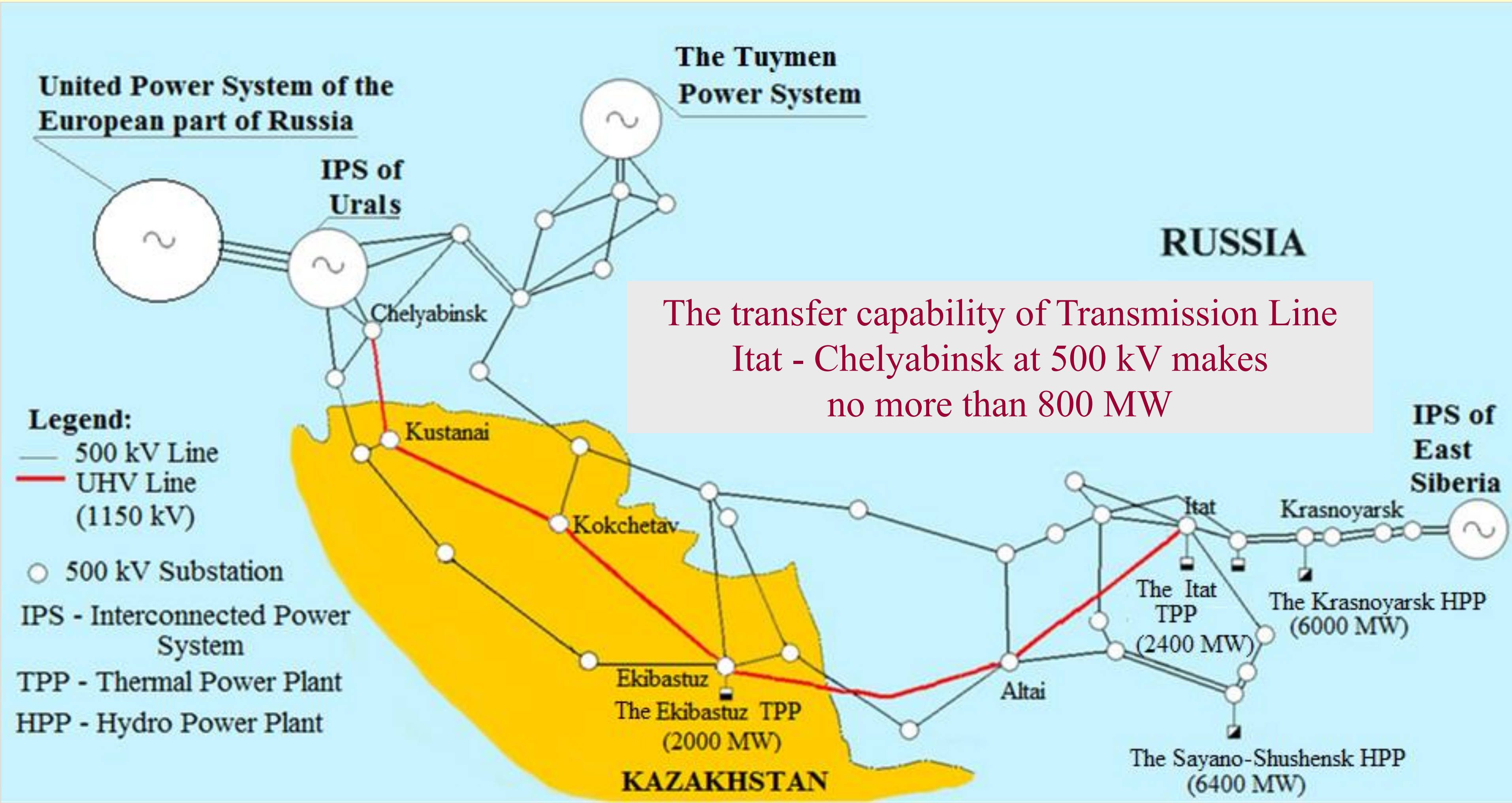
5. Regulation feature of normal conditions of HWTS was checked up and the opportunity of self-oscillation suppression at length a little less than half-wave was confirmed by use of forced voltage regulators.

6. The performed series of emergency conditions in the loaded HWTS showed its rather high stability at dynamic transitions. Internal overvoltages arising in these modes, and also in modes of single-phase short circuit did not surpass insulation level of 500 kV transmission system.

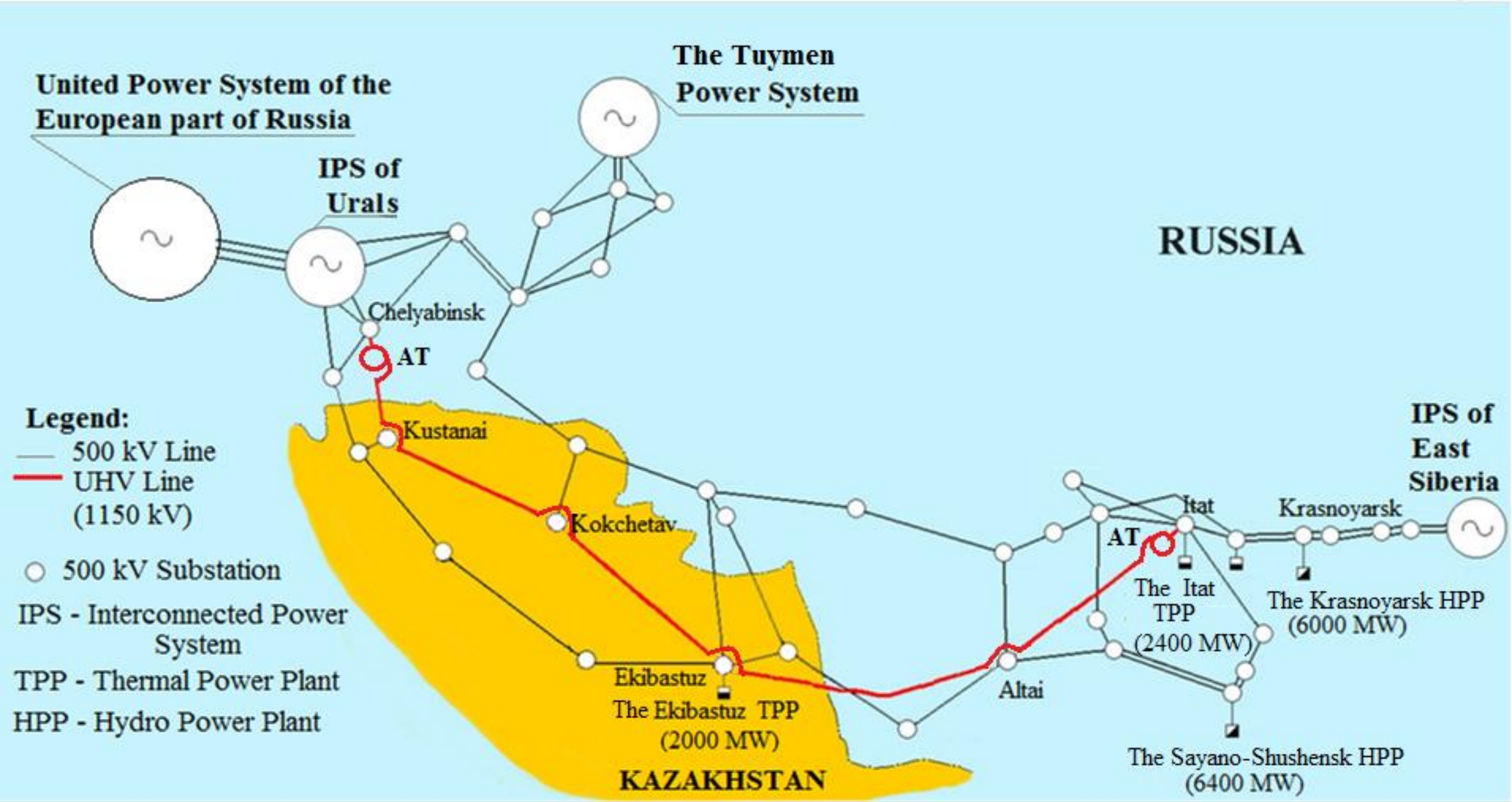
7. Use of existing schemes of relay protection and automatics and a number of additional measures enable to provide disconnection of HWTS under emergency conditions. At the same time it is necessary to develop special relay protection and safeguarding automatics.

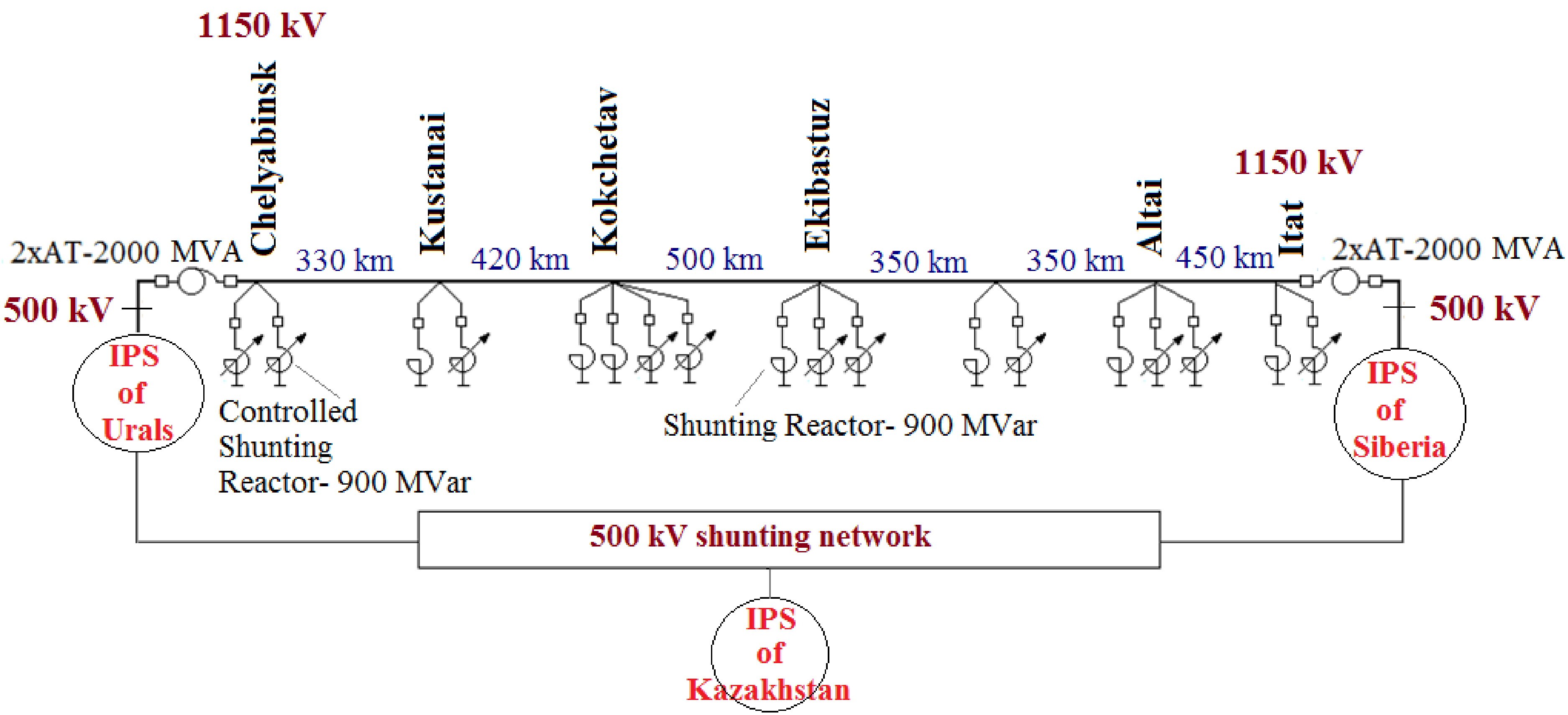
Part 2. Introduction of Half-Wave Technology in the Near Future in Russia

Scheme of backbone network Siberia - Urals

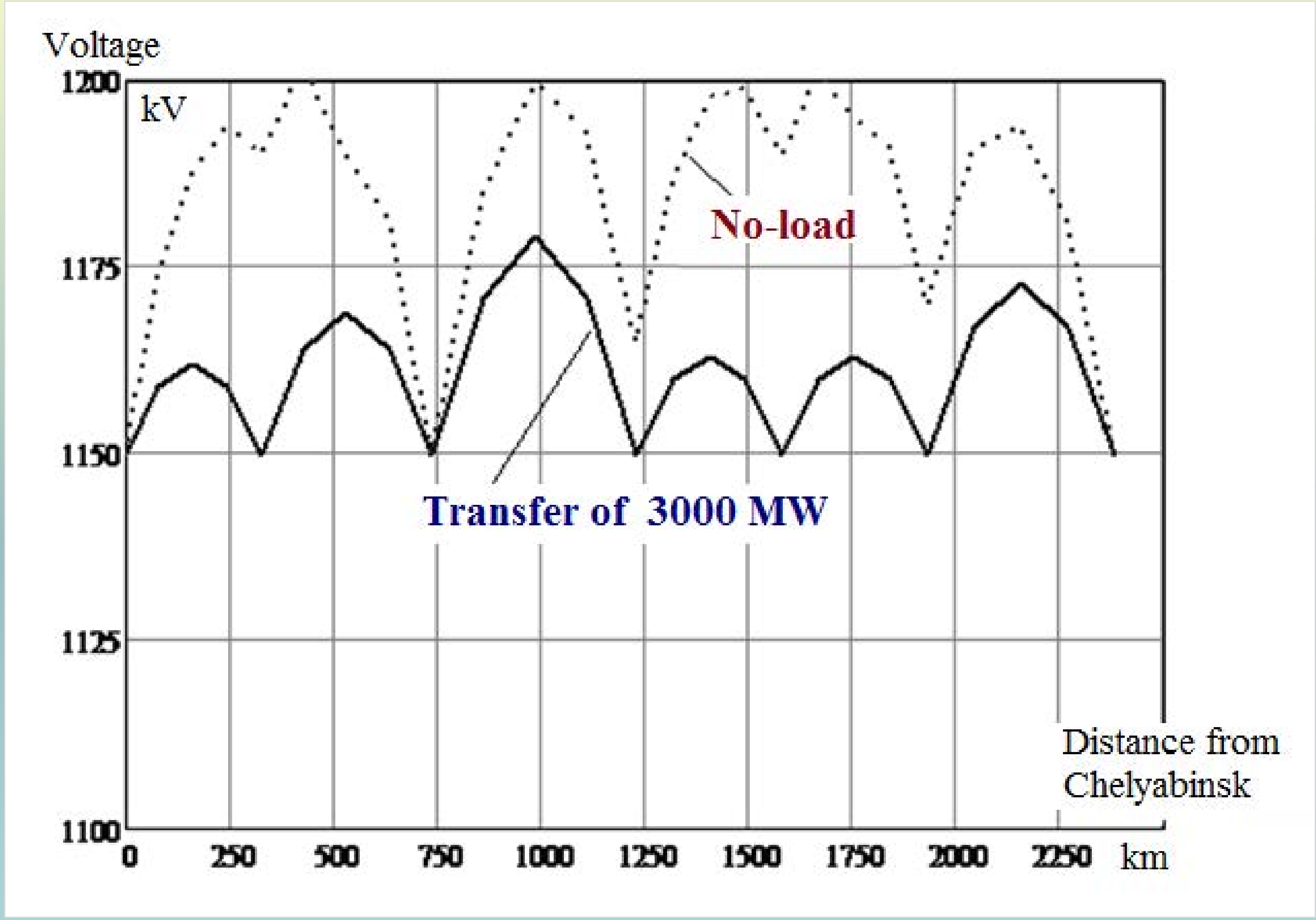


Direct uniting IPSs of Siberia and Urals without connection to network 500 kV at intermediate substations.



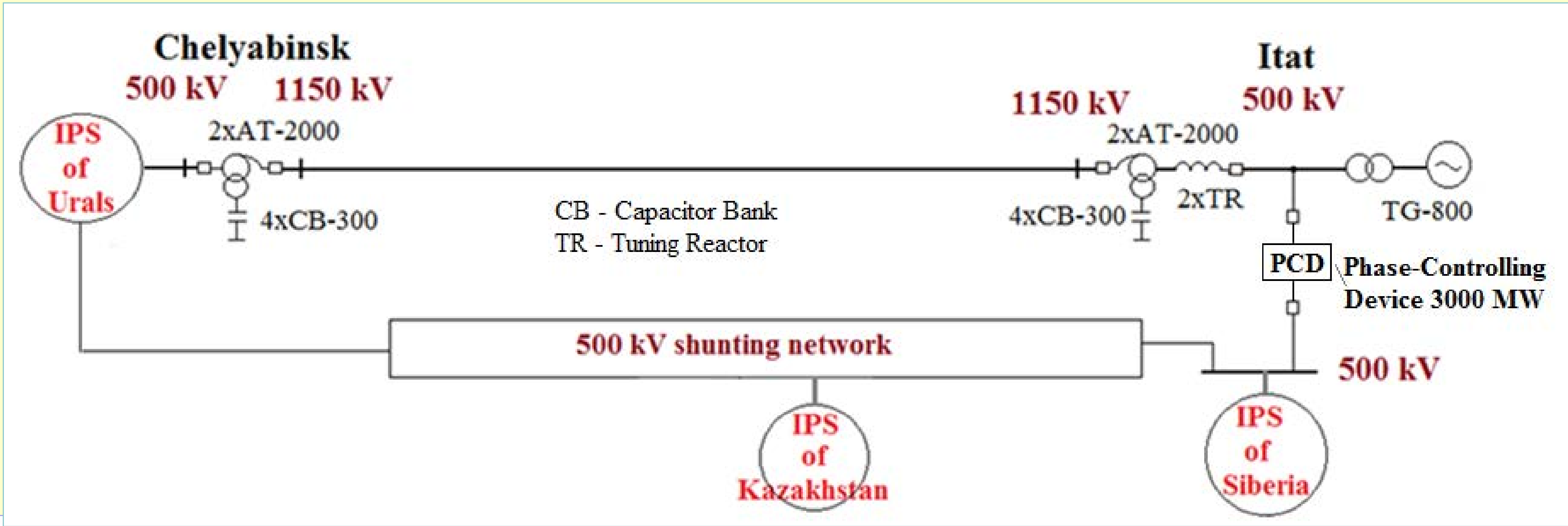


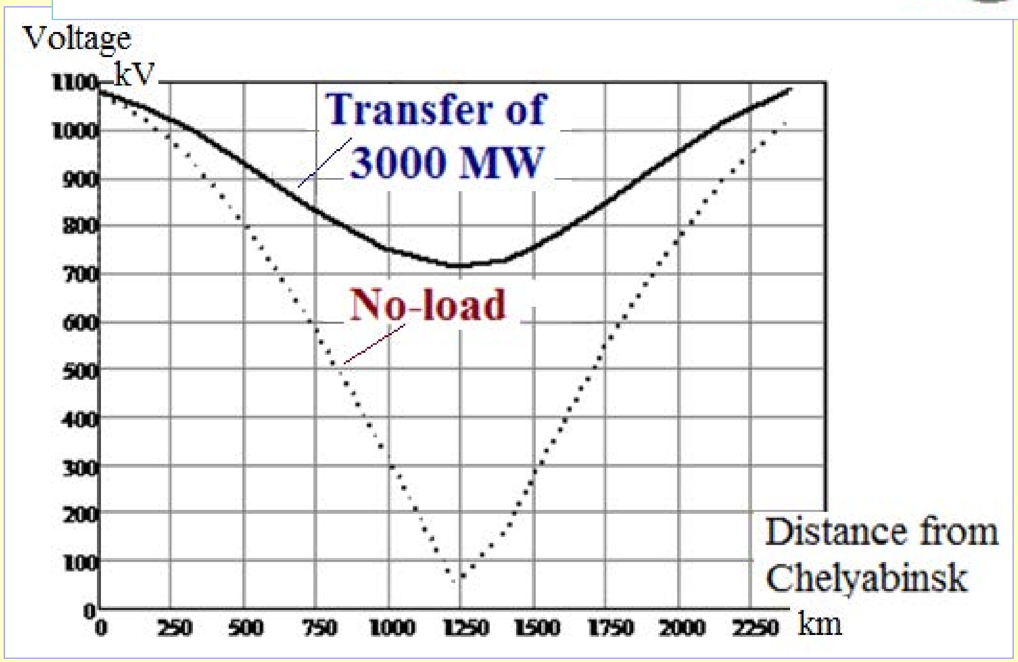
1150 kV 3000 MW Compensated TS Itat - Chelyabinsk



Voltage allocation along 1150 kV CTS Itat - Chelyabinsk

1150 kV 3000 MW HWTS Itat – Chelyabinsk

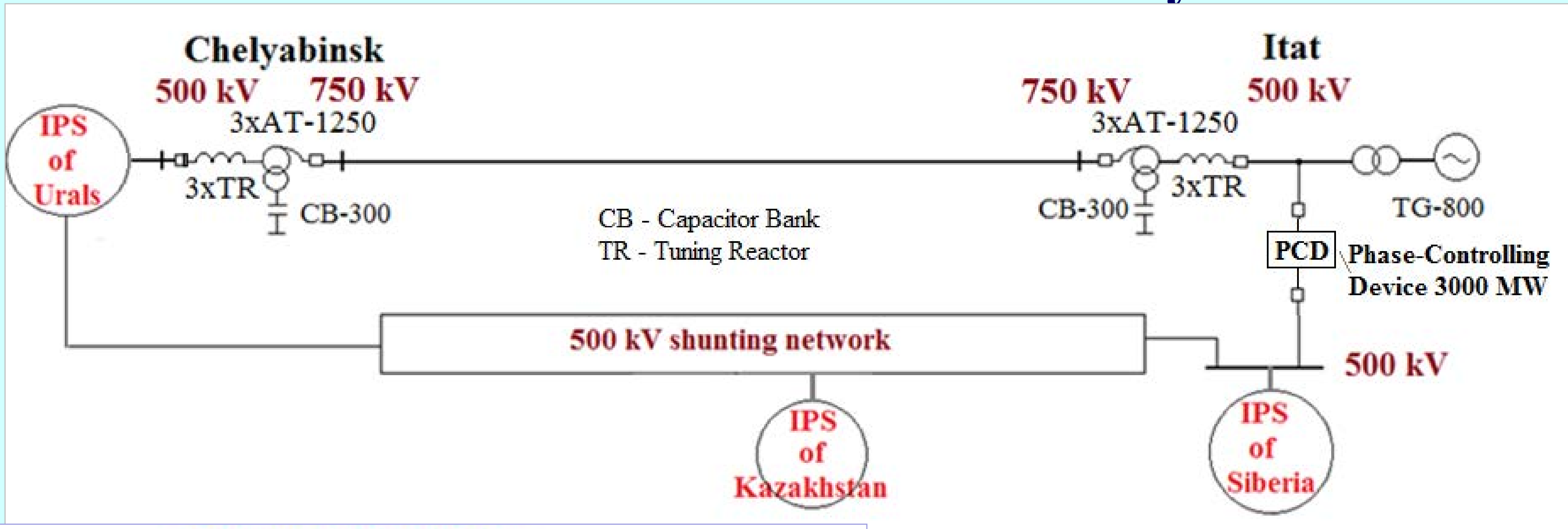


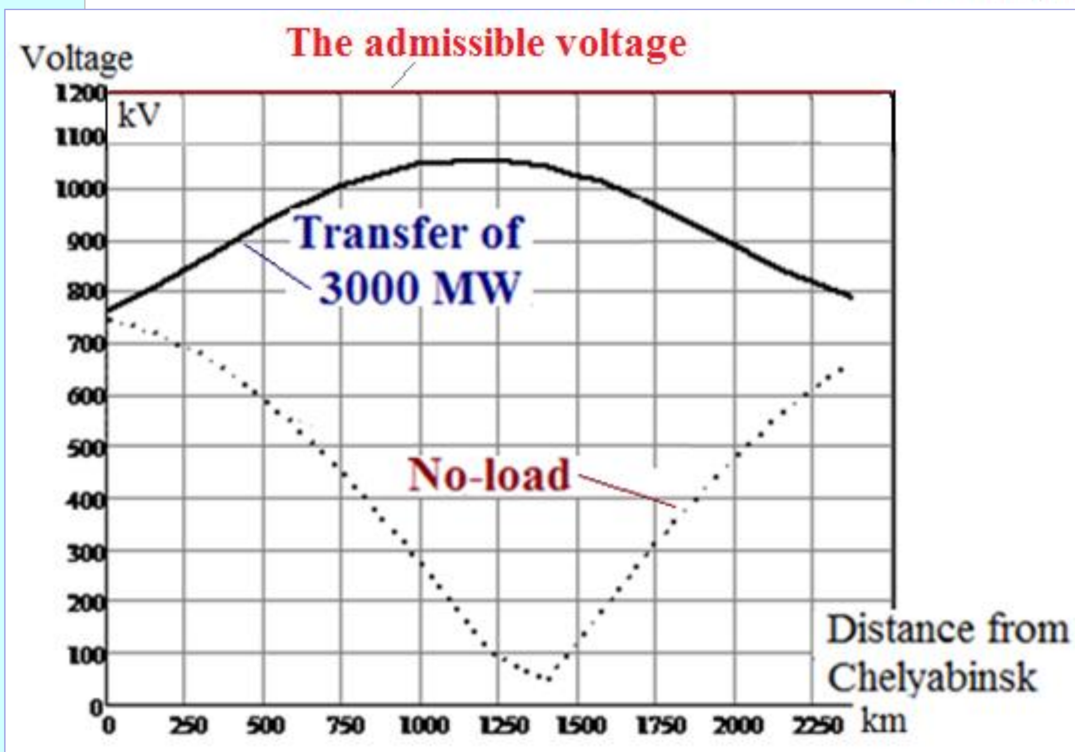


Parameters of tuning reactors (TRs) are: rated voltage 500 kV, rated current 2.3 kA and reactance 31.4 Ohm.

Voltage allocation along 1150 kV Line Itat - Chelyabinsk

750 kV 3000 MW HWTS Itat - Chelyabinsk





Voltage allocation along 750 kV Line Itat - Chelyabinsk

Technical and economic comparison of variants

Parameters	Variants		
	1150 kV CTS	1150 kV HWTS	750 kV HWTS
Capital cost, %	100	60	40
Efficiency, %	91.5	88.9	91.0

Conclusions to the part 2

1. 750 kV HWTS in comparison with UHV CTS is essentially cheaper and more simple in realization as it does not demand development and production of the various UHV equipment. For realization 750 kV HWTS it is necessary to develop only 500 kV tuning reactors and the phase-controlling device.

2. 750 kV HWTS can place in service till 2020.

3. Advent of 750 kV HWTS Itat-Chelyabinsk will promote introduction of future Half-Wave Transmission Systems in Russia and abroad.