Energy-efficient timetabling for mixed train flow. ELBRUS Automated Systems

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Mission of ELBRUS Family Automated Systems

Objective

Electric energy saving for train traction

Methods

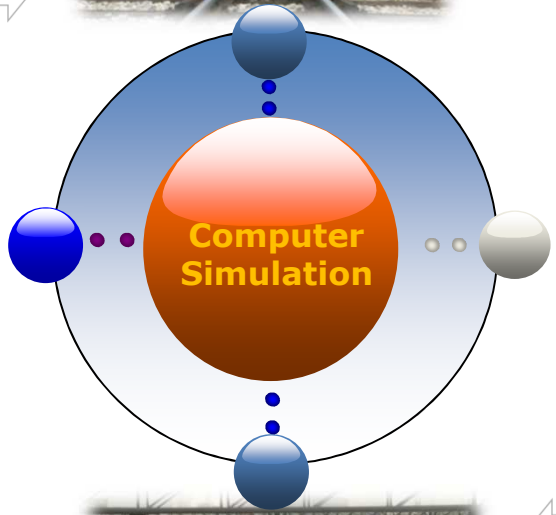
1. **APC ELBRUS** System: Energy-efficient train timetabling for short time planning (scope 1-14 days)
2. **ELBRUS-OPP** System: Energy-efficient train timetabling for dynamic planning (scope 2-6 hours)
3. **ELBRUS-EOS** System: Optimal train velocity and traction power control calculation

Core of the ELBRUS Computer-Based Simulation Model

Infrastructure data

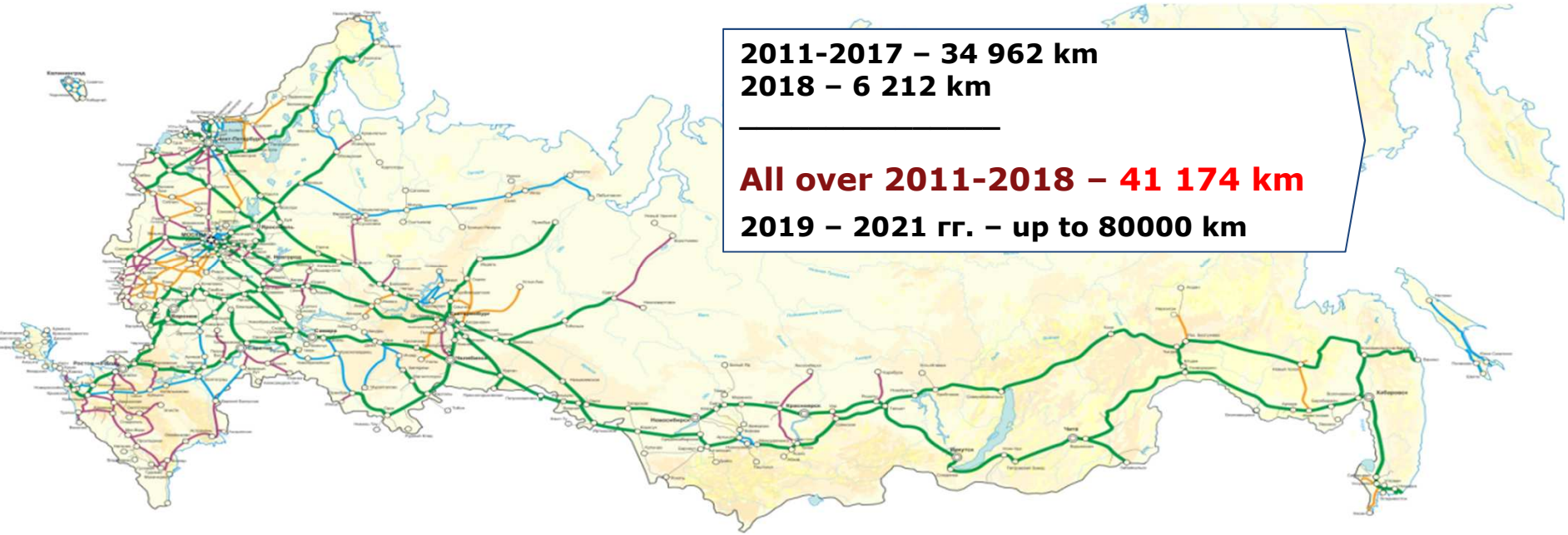
Train routes and features

Traffic control technology and rules



Actual limitations

APC ELBRUS Operational Area: from Far East to Europe Route

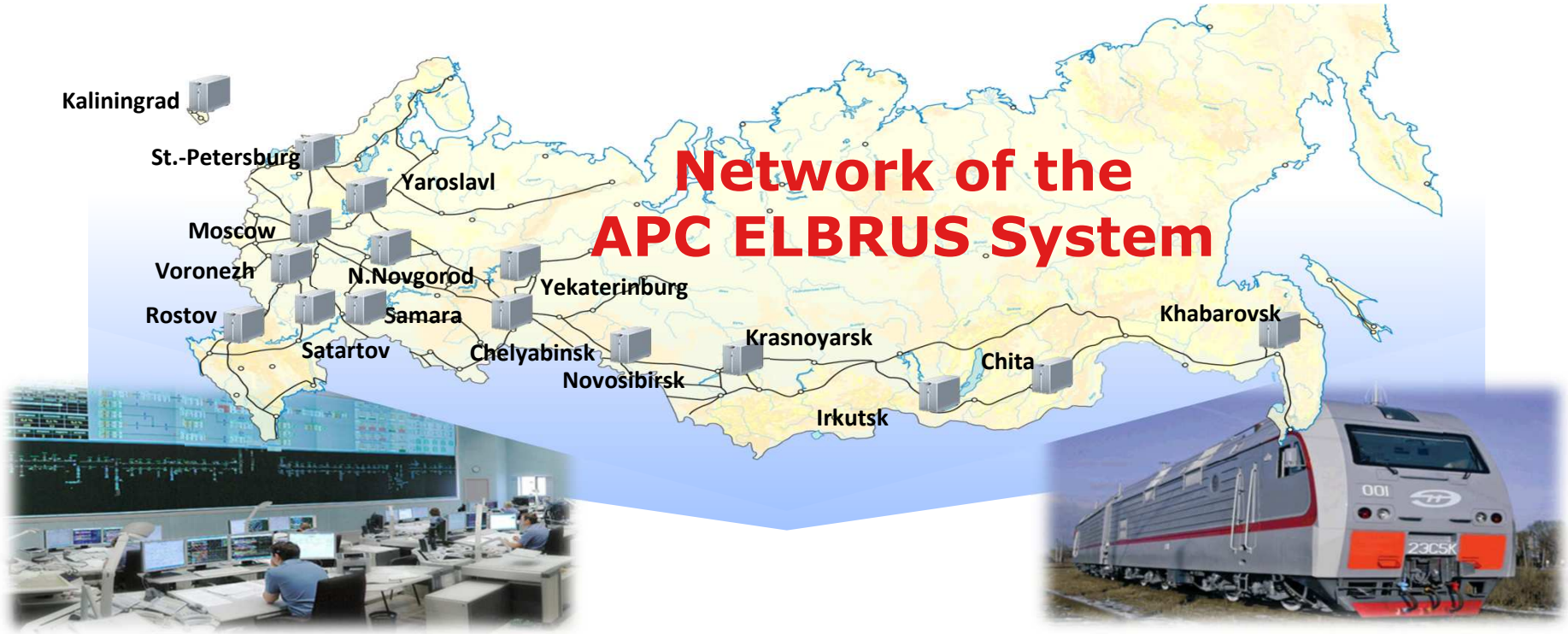


2011-2017 – 34 962 km
2018 – 6 212 km

All over 2011-2018 – 41 174 km

2019 – 2021 rr. – up to 80000 km

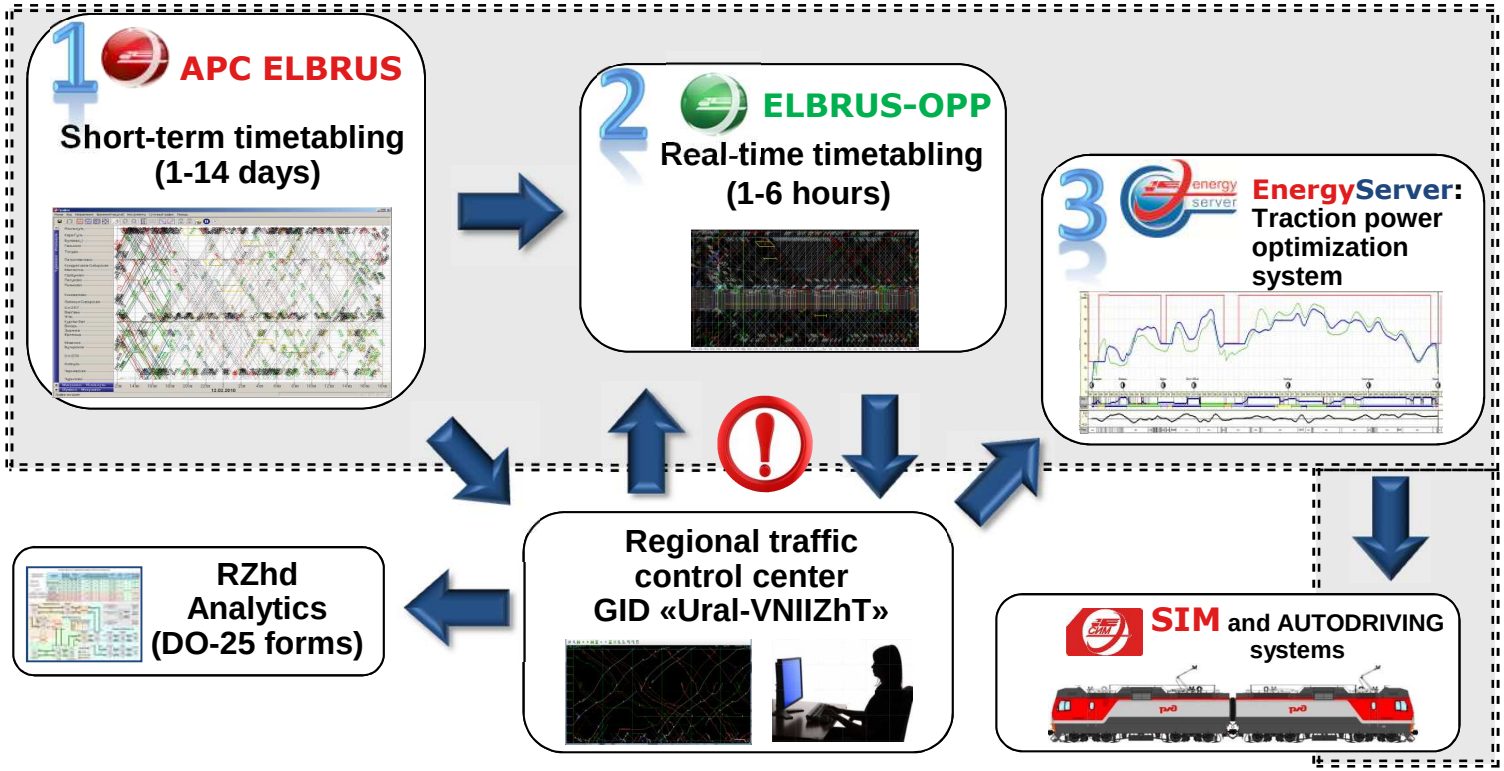
Cluster Network of the APS ELBRUS System over Russian Railways



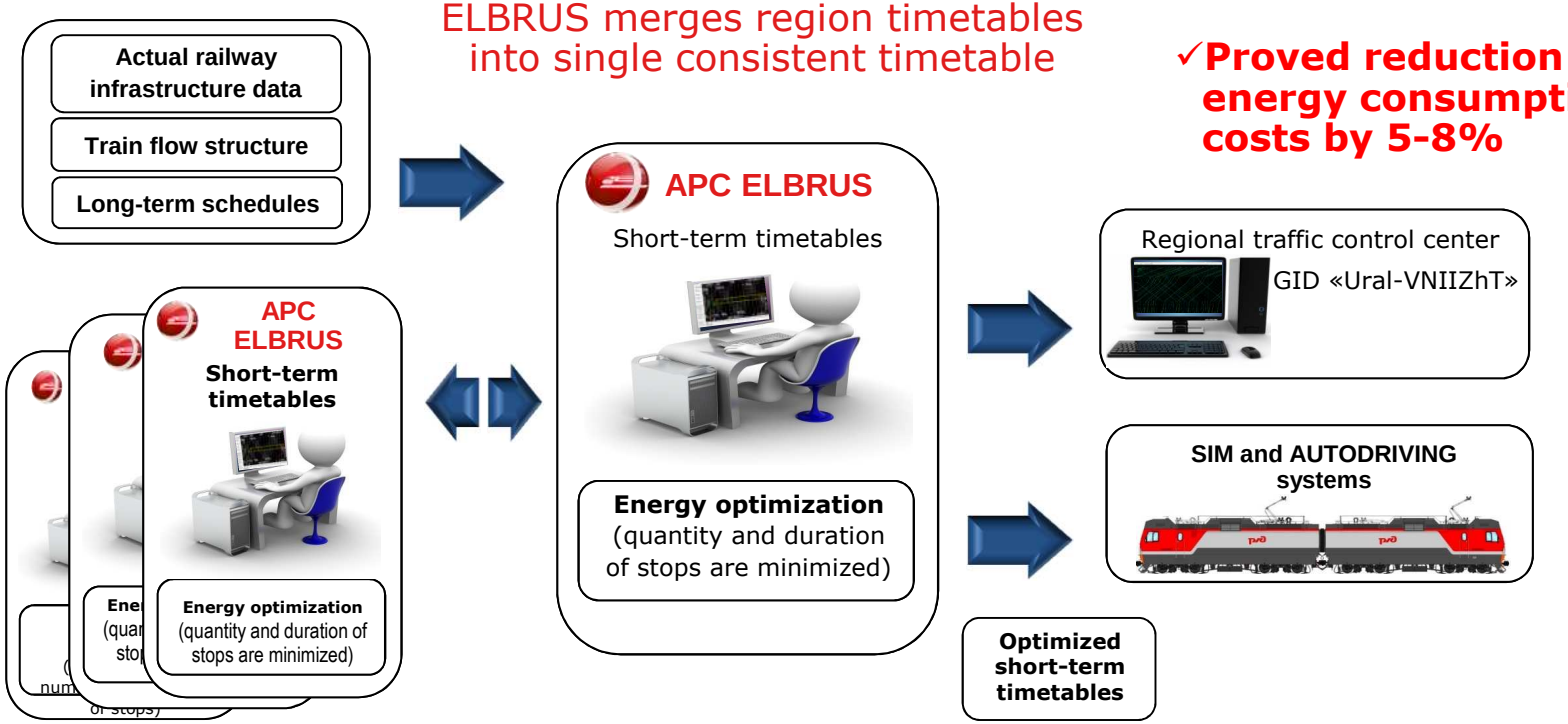
Regional Train Dispatching Centers

SIMs – Locomotive Driver Informing Systems

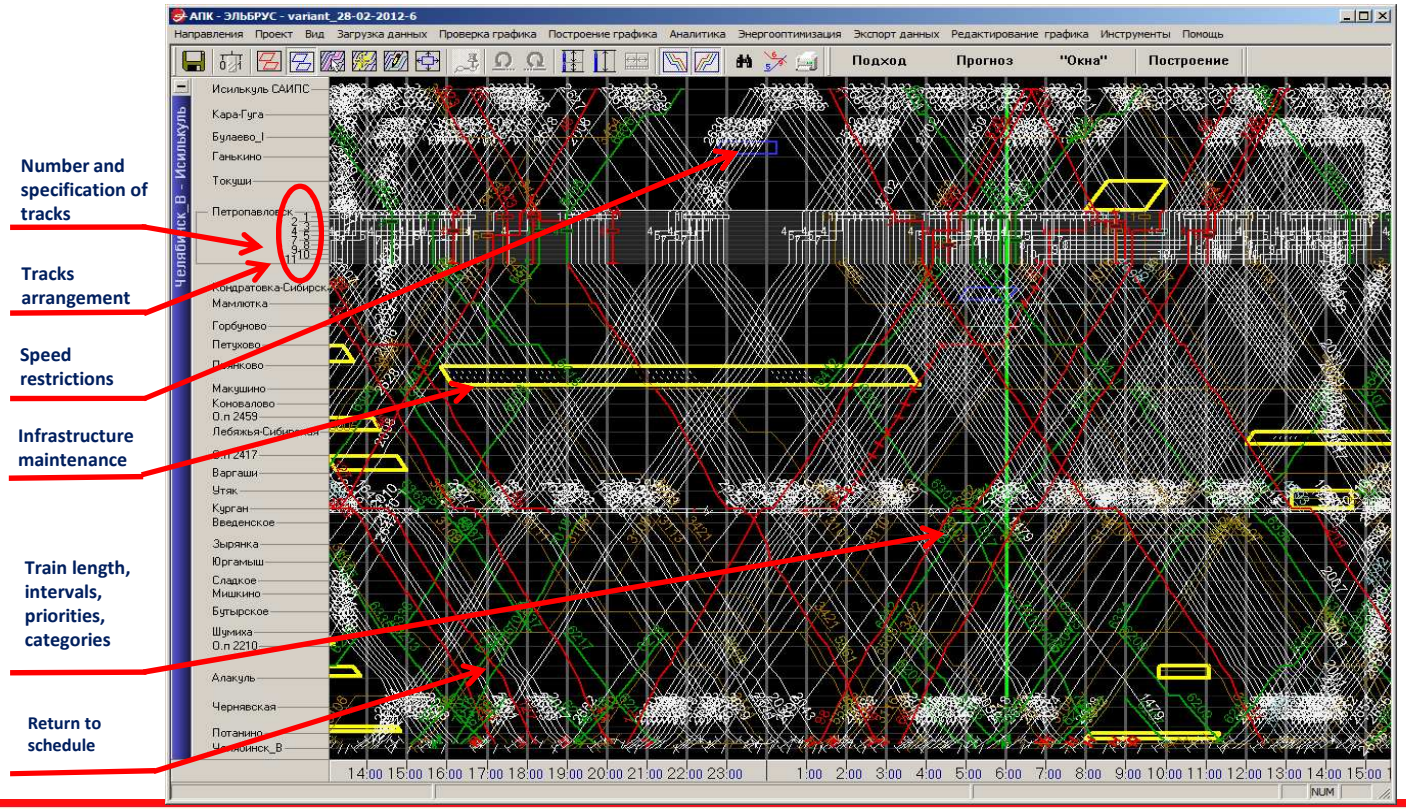
Automatic Train Schedule Management Systems of the ELBRUS Family



APC ELBRUS: Technology of the Energy-efficient Short-term Timetabling

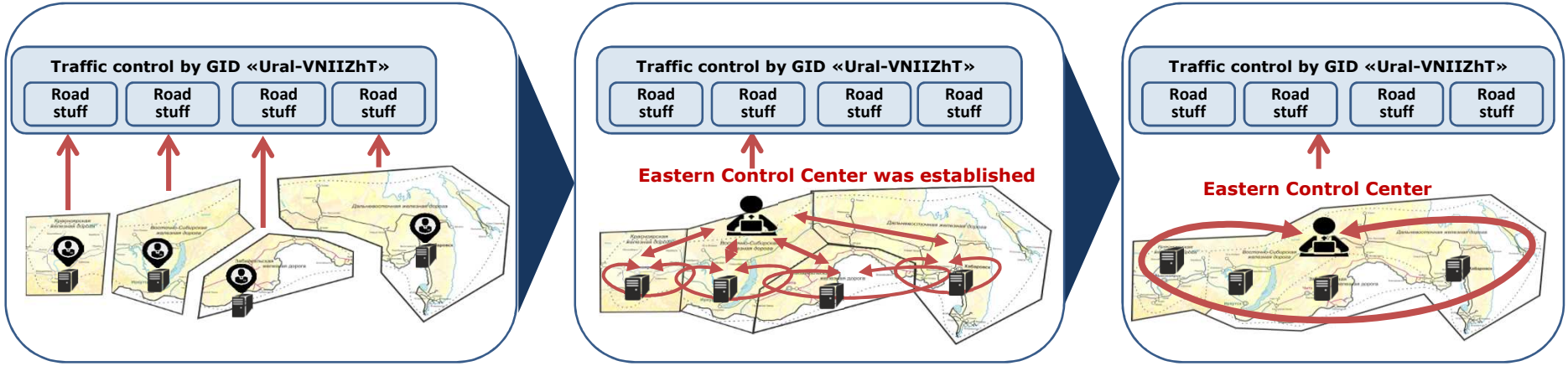


APC ELBRUS Operation Mode: Short-Term Timetabling



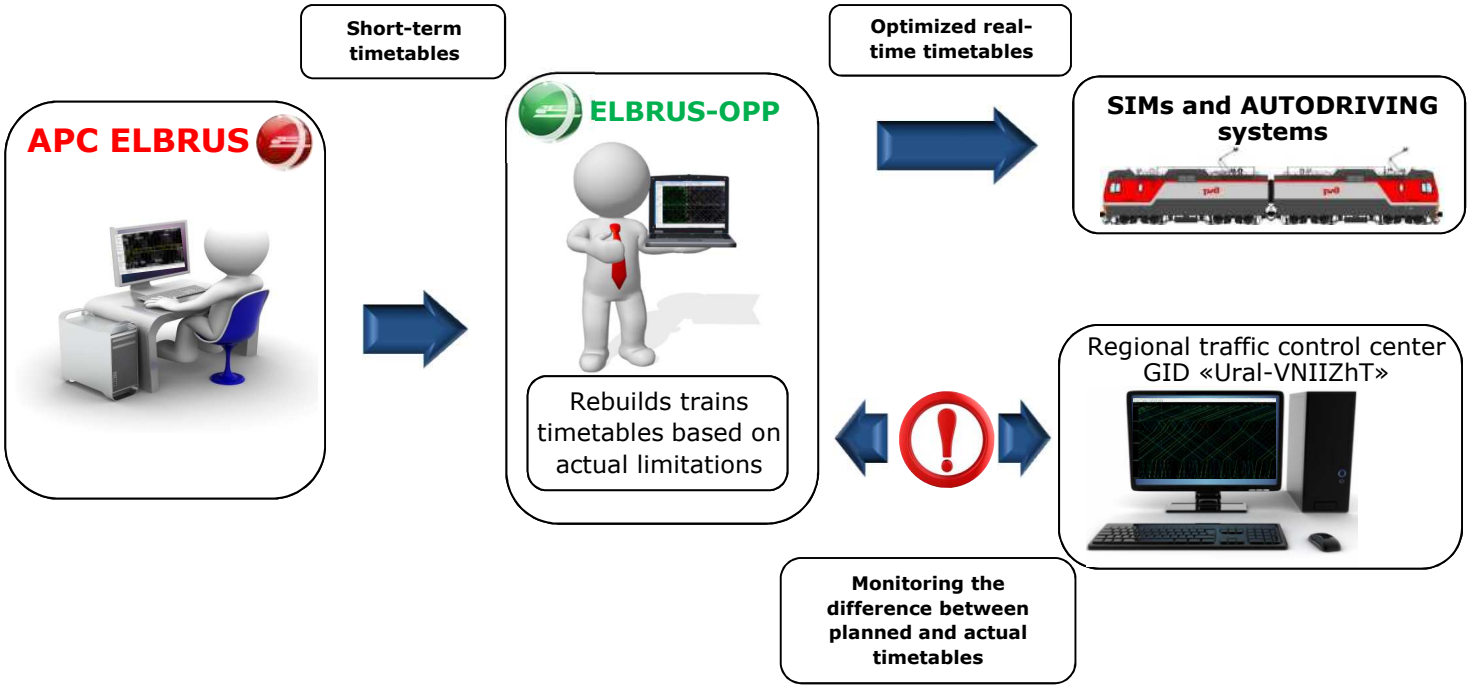
APC ELBRUS Evolution After Eastern Control Center of Russian Railways was Established

Eastern Control Center of Russian Railways now is responsible for **11 876 km** of railways over 4 divisions of RZhD

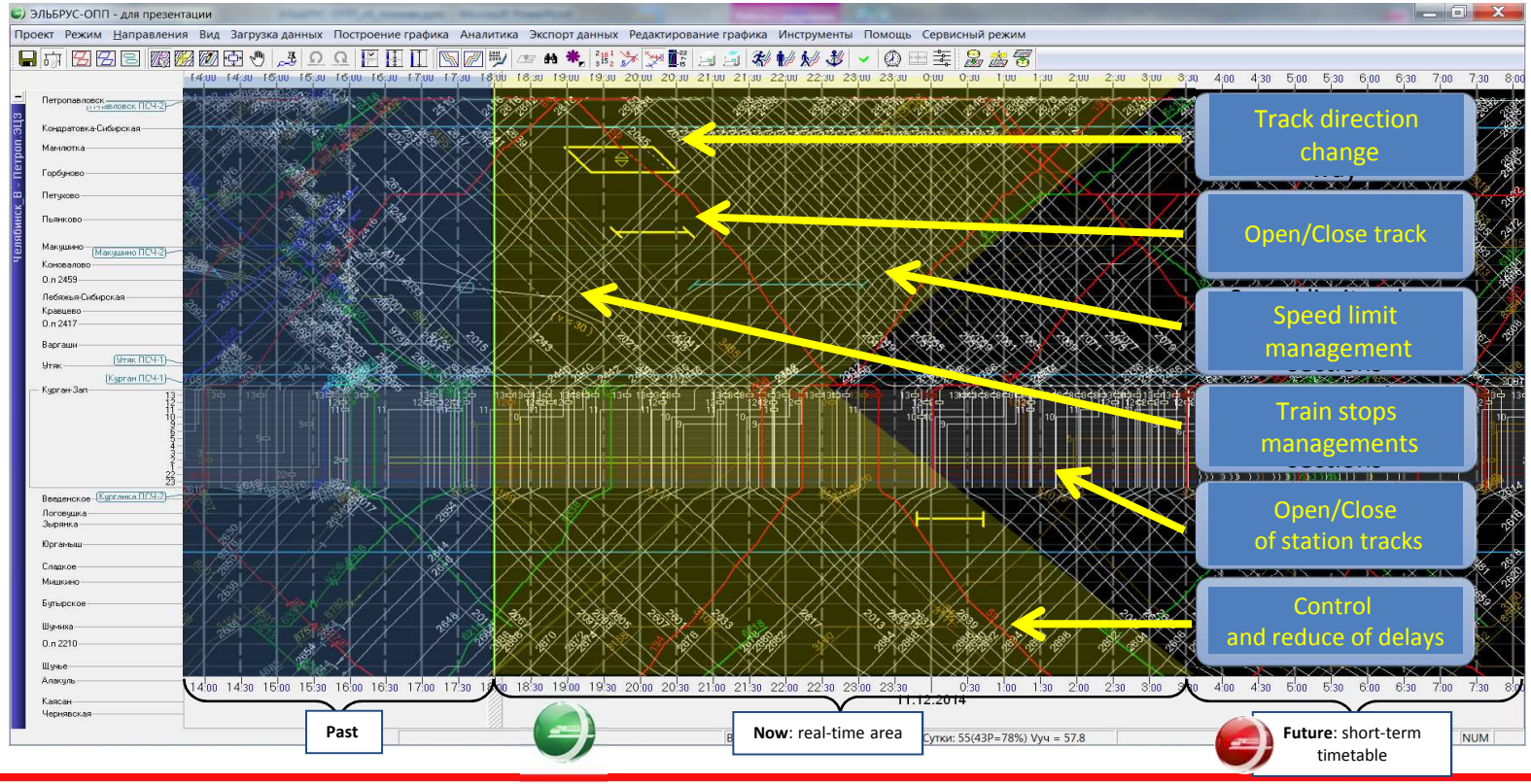


before 2012 **2016** **2017**

ELBRUS OPP: Real-time Energy-Efficient Timetabling Technology



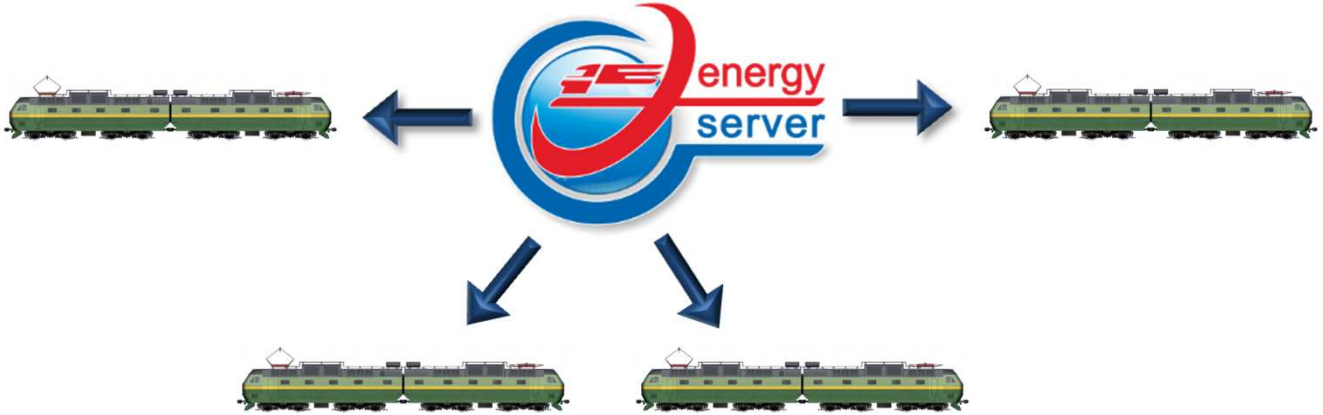
ELBRUS OPP: Real-time Energy-Efficient Timetabling



EnergyServer: Fine-Grained Traction Power Optimization System

Objective

Optimal train velocity and traction power control calculation



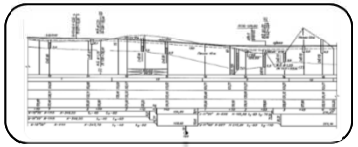
Methods

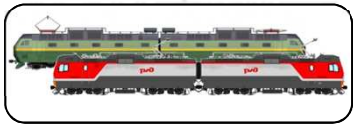
- Optimal traction power control calculation service
- Unified way to bring energy optimization functionality to different automated systems (“Enegry Optimization Factory”)

EnergyServer: How Energy Optimization Factory Works

Input data:

- ✓timetables
- ✓speed limits
- ✓track profile
- ✓locomotive specs
- ✓train cars specs

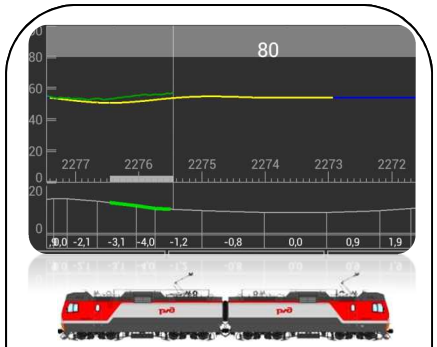




energy server

Speed and traction power control as function of time

✓ **Electric energy saving (5-8% per trip)**



SIM and AUTODRIVING systems

EnergyServer: Mathematical Model of Energy Optimization

Traveling time determination by common train path (TP)

$$m\frac{dv(t)}{dt} = F_т(t) - B(t) - W_n \qquad \textbf{If} \quad V(t_o) = V_o$$

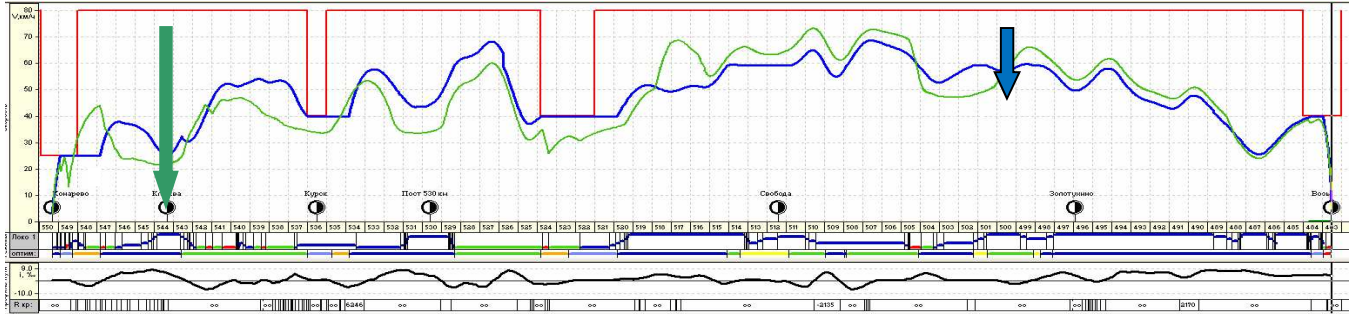
Train velocity – V(t) locomotive power – Fт, speed train resistance – Wn and conditions, train velocity at the beginning - Vo

Traveling time determination by means of energy optimal train path (ETP)

$$m\frac{dv(t)}{dt} = F_т(t) - B(t) - W_n \qquad \textbf{If} \quad V(t_o) = V_o \ \textbf{and} \ V(t_к) = V_к$$

and also $A = \int_{T_н}^{T_к} F(t)\cdot V(t)dt \Rightarrow \min$

The solution of differential system of ETP equations reflects both the restrictions to infrastructure parameters, and providing minimum consumptions of energy



Traveling time between stations, min

ETP 1:29	13	11	7	22	16	20
TP 1:29	15	13	8	23	13	17

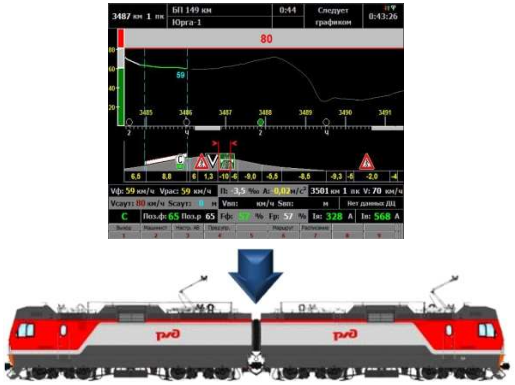
Electric energy consumptions, kWh

ETP 1334	220	195	94	330	270	225
TP 1440	180	160	85	315	390	310

SIM: Locomotive Driver Information Systems

Usage in the automatic train driving systems:

- ✓ timetable
- ✓ track profile
- ✓ traction power modes and velocity
- ✓ locomotive cab data



Usage for mobile devices:

- ✓ timetable
- ✓ track profile
- ✓ traction power modes and energy-optimal velocity

ELBRUS-SIM

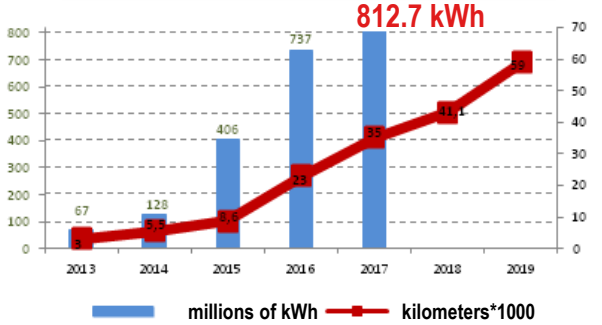
ELBRUS Systems Energy Efficiency Over 2011-2018

Energy-efficient timetabling for mixed train flow with minimal energy consumption → SIMs and AUTODRIVING systems

Actual timetables for optimal planning the required number of locomotives and drivers → RZhd Analytics (DO-25 forms)

Harmonization of the transportation process over large operational areas → New large-area dispatchering

Years	APC ELBRUS works at
2011 - 2014	8 641 км
2015	6 954 км
2016	7 670 км
All over 2011-2016	23 265 км
2017	11 697 км
2018	6 212 км
All over 2011-2018	41 174 км and 16 all Railways of RZhD



Traction power saved, kWh: (4÷5%)

Speed increased: (10÷12%)

APC ELBRUS Summary

1-st Prize of UIC in 2012:

APC ELBRUS works over 42 000 km of Russian Railways

Russian Railways saved 812.7 millions of kWh in 2017

Thank you for your attention and time!

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