# Electro Energetic Technological Control in East Siberia Railway

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**By system analysis and imitating modeling authors show the most effective modern techniques for railway electric systems control. Modern measure technologies PMU-WAMS and smart grid allow to solve real time tasks of centralizing control of railway electric systems. Quantity characteristics of control effectiveness are determined.**

**By computer modeling there is shown the situation approach for practical tasks of railway electric system control.**[1]

***Key words:*** **railway electric systems, technological control**

## I. INTRODUCTION

East Siberian and Far East electric system's nets nearly bind with railway electric substations. It is needed to take into account the feature of the electric traction loads in technological control of these systems.

Railway electric system is complex nonlinear dynamics object [1]. For state control one can use the next techniques:

- Regulating reactive power compensation plant (RPCP);
- Regulating series capacity;
- Blocks of automatic regulation of transformer coefficient (ARTC);
- Superconductive inductive energy accumulator;
- Capacitive energy accumulator;
- Active harmonics conditioner;
- Regulating booster transformer [2];
- Synchronous and asynchronous distributing generators with automatic energizing [3].

It needs to say that ARTC is widely used in electro energetic systems [4] but not in railway electric systems. This is by follows:

- High velocity of contact net voltage variations and high magnitude of its variations, more that are in common electric nets;
- Low dependability of ARTC of traction transformers.

ARTC can be used for rare correction of railway electric system state.

On fig. 1 there is shown the whole composition of control installations for railway electric systems. This composition is according to 'smart grid' conception, the modern vector of world electro energetic.

The whole composition of control installations can not be absorbed on each traction substation by economic and technological reasons. Some installations accomplish the same functions.

The main tasks of these installations are follows:

1) Contact net voltage stabilization;
2) Abatement of energy losses;
3) Abatement of voltage variations on 220-110 kV and 6-10-35 kV buses of traction substations;
4) Abatement of voltage asymmetry on 220-110 kV and 6-10-35 kV buses;
5) Abatement of high harmonics on 220-110 kV and 6-10-35 kV buses of traction substations.

Main feature of control installations are illustrated on fig. 2. Computer modeling results of some effects are written below.

## II. CONTACT NET VOLTAGE STABILIZATION

Analyze of RPCP for contact net stabilization was made for railway section 1×25 kV with 9 traction substations and 8 traction nets between them. Diagram of locomotive voltage is shown on fig. 3 for 6300 tons train and 10 Mvar RPCP. It is shown that RPCP significantly reduce the voltage variations on locomotive.

Modeling was made for studying of booster transformer and booster aggregate [2] effectiveness. On fig. 4 there is shown the dynamics of locomotive voltage for train mass 5200 tons with standard energy supplying and with

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booster transformer and with booster aggregate. One can see that voltage stabilization with boosters is significant.

Voltage stabilization on 6-10-35 kV nets with distributing generators is illustrated on fig. 5. Fig. 5 shows the modeling results of non traction loads that are supplied from traction substations [3]. Maximum voltage variations take place on 0.4 kV phase “B” of far substation where voltage reduces to 160 V for a short time. 480 kvar distributing generator increases minimum voltage by 24 V and increases medium voltage by 17 V.

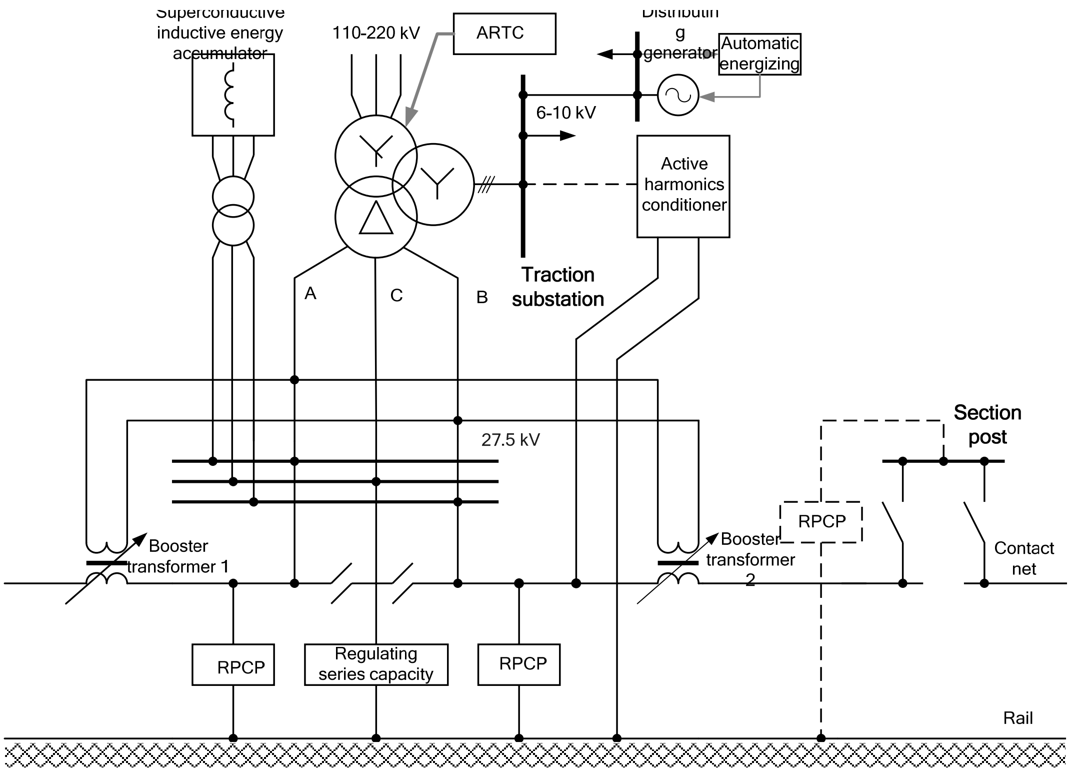


Fig. 1. Control installations placement

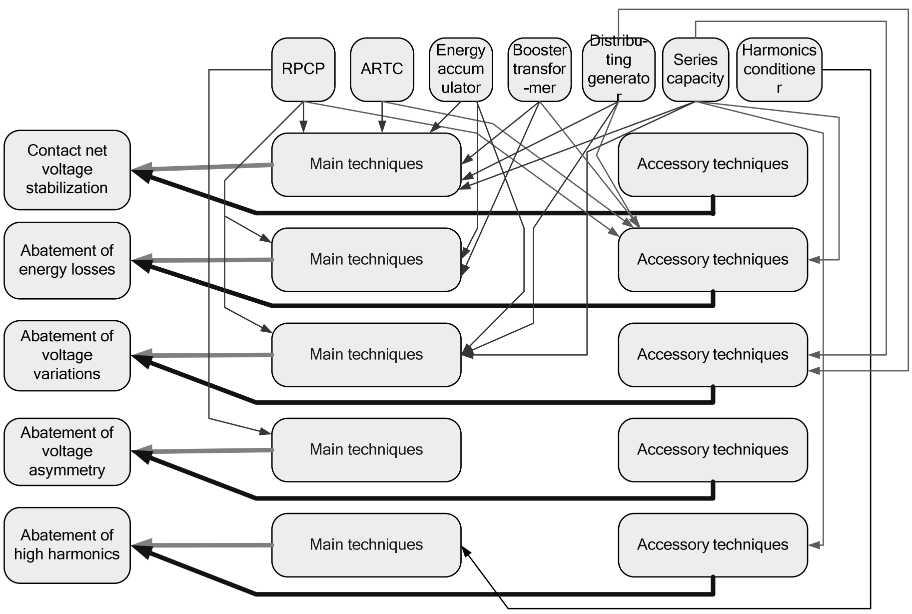


Fig. 2. Correlations of control installations

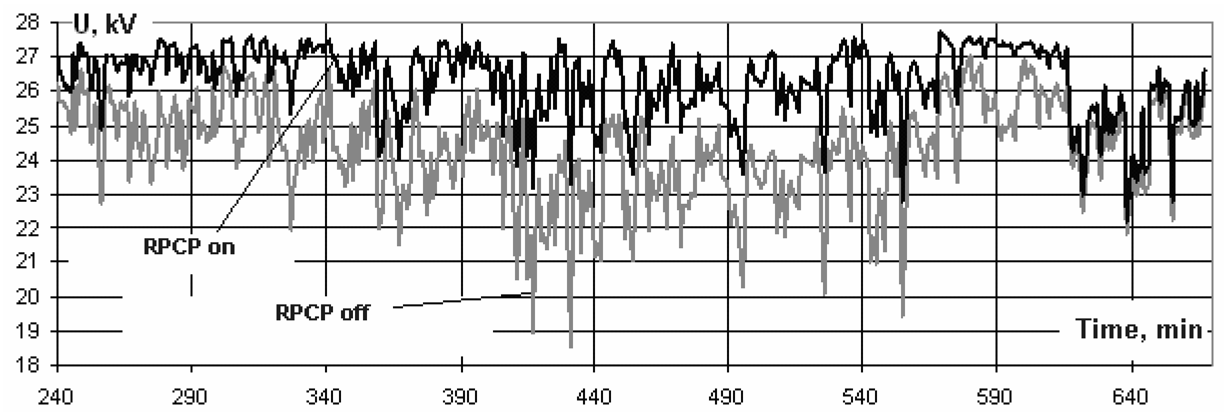


Fig. 3. Locomotive voltage of train 6300 tons

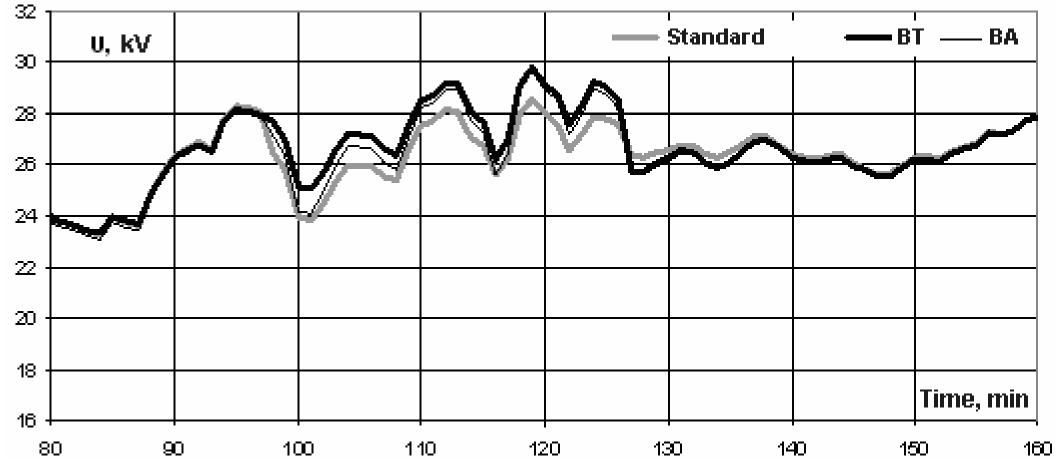


Fig. 4. Locomotive voltage of train 5200 tons

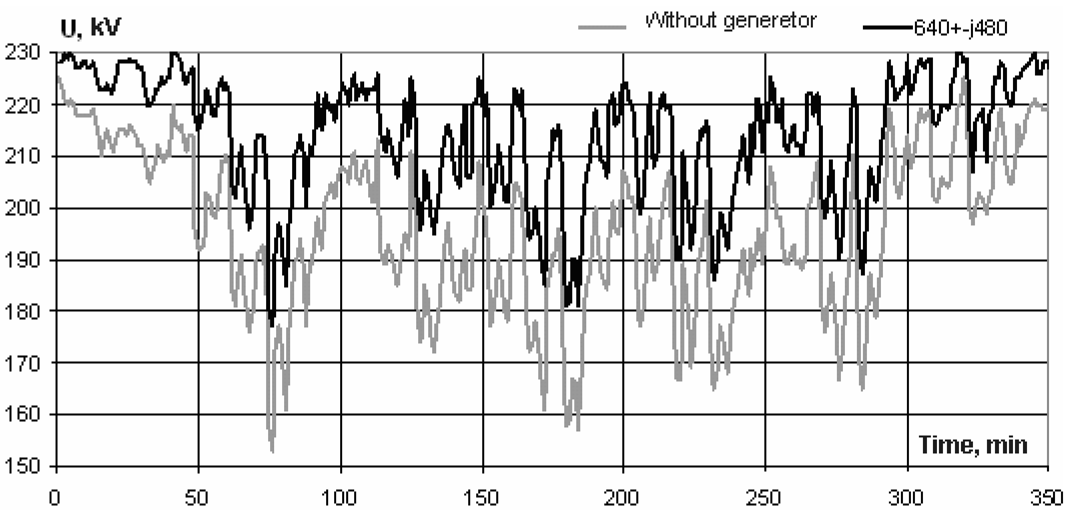


Fig. 5. Phase "B" voltage variation when trains moving

III. ABATEMENT OF ENERGY LOSSES

Imitating modeling of real railway section shows that RPCP reduces traction net losses by 20..30% with practically constant transformer losses. RPCP on section post is more prefer than RPCP on traction substation. Evaluation shows that difference between two places is

$$\Delta W_{TS} - \Delta W_{SP} = 0.006 W_{\Sigma},$$

where $\Delta W_{TS}$ – energy losses when RPCP is on traction substation; $\Delta W_{SP}$ – energy losses when RPCP is on section post; $W_{\Sigma}$ – sum trains' energy.

Voltage level is higher with series capacity but losses may be more; this fact was marked in [6]. Higher losses are determined by redistribution of power flows from nearby substations with higher currents and higher losses in transformers. Traction net losses are practically constant.

Energy losses may be reduced by means of energy accumulators. This allows reducing power form factor with up to 6 times smaller losses [7].

## IV. ABATEMENT OF VOLTAGE VARIATIONS ON BUSES OF TRACTION SUBSTATIONS

RPCP with high harmonics filtration allows improve the next quality factors:

- Reducing voltage variations on traction substation buses;
- Reducing voltage asymmetry;
- Reducing values of current and voltage high harmonics.

High speed RPCP (with regulating time 5..20 ms) allows the voltage variations very much down.

Abatement of voltage variations are by reducing of currents on 27.5 kV of traction substations, fig. 6.

Voltage variations may be reducing by means of energy accumulators that allow improving instability of state [7].

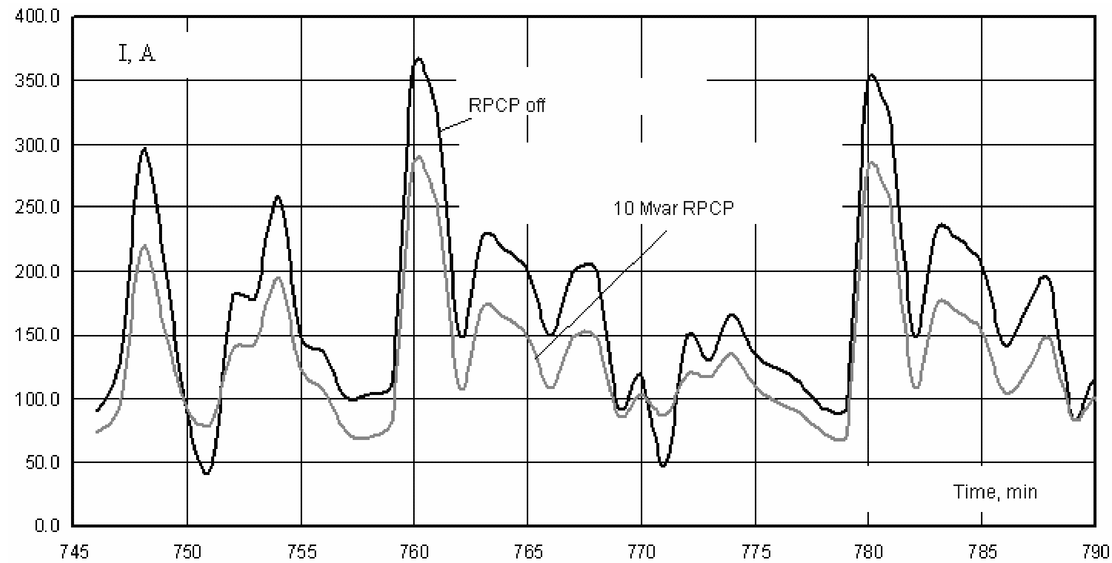


Fig. 6. Contact net current at traction substation with 72 pairs of trains

## V. ABATEMENT OF VOLTAGE ASYMMETRY AND HIGH HARMONICS ON BUSES OF TRACTION SUBSTATIONS

RPCP with phase regulating allows twice reducing of asymmetry factor $k_{U2}$ on higher voltage buses of traction substations (fig. 7). Asymmetry reducing depends on trains moving, short circuit power and large declines near substations.

Active harmonics conditioners are the most effective for reducing of high harmonics on 6-10-35 kV buses [8, 9]. In paper [9] active harmonics conditioner on traction substation was modeling with MATLAB system. Traction current THD without filtration was equaled 26 %, but with active harmonics conditioner THD reduced to 5.3 %.

Appliance of active harmonics conditioner is not only for reducing of voltage THD on 6-10-35 kV buses but for reducing current THD of traction winding.

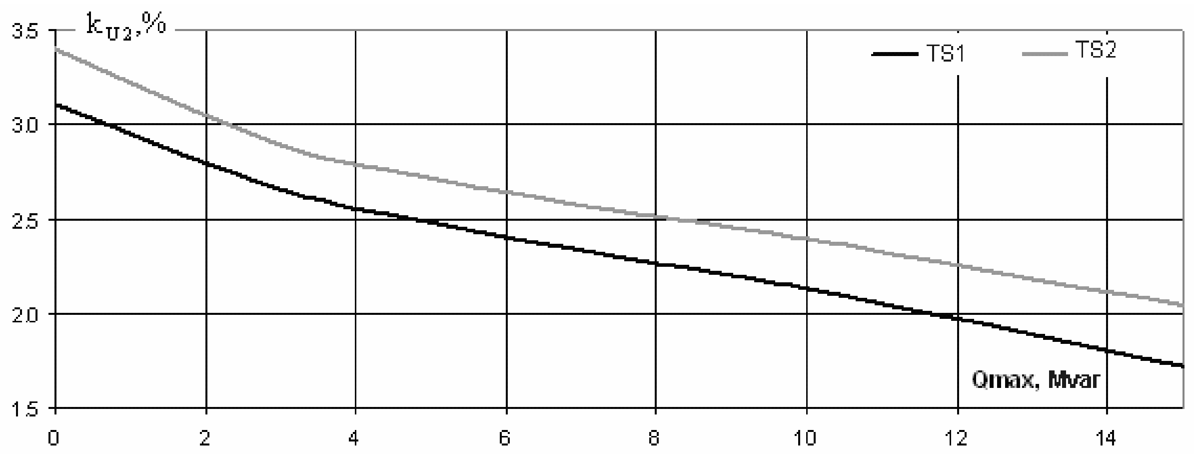


Fig. 7. Coordination between variation of asymmetry factor and value of maximum reactive power Qmax of RPCP

## VI. INFORMATION SUPPORT OF RAILWAY ELECTRIC SYSTEM CONTROL

In modern railway transport leading information systems are applied for exploitation, train moving, electric systems [10, 11]. Available information resources may be used for operating and automatic control of railway electric systems [1]. But equivalency and situating control [12, 13] needs synchronized measurement of electric parameters. This measurement can be realized by PMU-WAMS technology now prevalent on common electro energetic [14].

Now using of Phasor Measurement Technology is the priority of electro energetic technology. Wide Area Measurement System uses for improving of information in common electric systems control. WAMS allows synchronized measurement using cosmic apparatus of global position (GPS, GLONASS). Most effect may be obtained on real time control and state estimating of electric system.

Control system comprises multifunctional registrations hooking up current and voltage transformers. Measurements on far objects synchronize with GPS. Such techniques allow solving complex tasks of centralized control in real time process.

## VII. SITUATING CONTROL OF RAILWAY ELECTRIC SYSTEM

Complexity, nonlinearity and dynamics features make hard control of railway electric system. This hardness may be getting over by situating control. Situating control is the control based on distinction of some typical situation and decision of the problem. Effectiveness of situating control was studied on scheme of real railway section [15].

Modeling results on fig. 8 show that situating control allows solving actual tasks.

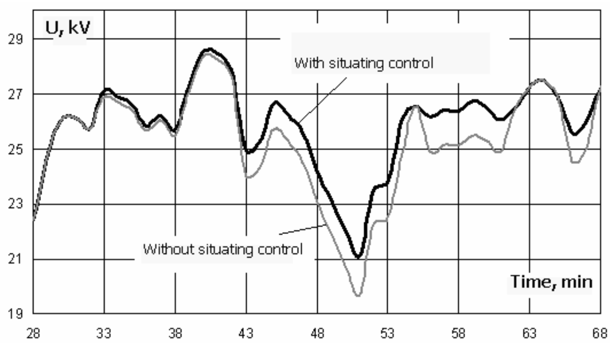


Fig. 8. Locomotive voltage with and without situating control

Without situating control locomotive voltage on 49...52 min is extremely low. Voltage is allowable during all modeling time when situating control is made with RPCP that places between second and third substations.

## VIII. CONCLUSIONS

1. The most effective control of railway electric systems may be made by regulating reactive power compensation plant, regulating series capacity, blocks of automatic regulation of transformer coefficient, superconductive and capacitive energy accumulators, active harmonics conditioners, regulating booster transform-

ers and distributing generators with automatic energizing.

2. Imitating modeling shows that modern control technique allows stabilizing contact net voltage, advancing energy quality and reducing energy losses.

3. Situating control method allows operating with only some typical situations.

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## X. BIOGRAPHIES

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