

3.2. Optimization of the Electric Power Mode of Power Systems, S. Zaitseva, Sh. Khisoriev, and A. Savitsky

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INTRODUCTION

This work was carried out within the Environmental Policies and Institutions for Central Asia Program (EPIC) sponsored by the US Agency for International Development (USAID). In creating the model of planning water and energy modes of the Naryn – Syr Darya Cascade, there arose the necessity to develop an electric power mode model for power systems of Central Asia to apply this model while solving operational problems.

PROBLEM STATEMENT AND GENERAL REQUIREMENTS TO THE MODEL

Changed economic relations in the republics of the former Soviet Union, including Central Asian Republics, new structures appeared in the mode operation hierarchy of power systems, and developing capabilities of computer engineering and modeling algorithms make it necessary and possible to revise methods used to solve the problem of optimizing the daily mode of power systems.

The problem stated by the EPIC Program supposed the following requirements to the model:

- ✓ The model should determine an optimal load of regional stations with regard to an assigned set of hourly and integral daily technological and mode constraints.
- ✓ The optimization criterion should be consistent with economic interrelations in modern society and change as these interrelations change.
- ✓ The model should be applicable for calculations on different levels of the operation hierarchy.
- ✓ The model should be applicable for both short-term and long-term planning.

The modeling language GAMS (General Algebraic Modeling System) may help meet these requirements. This modeling language enables you in quite a simple way to build mathematical

models of actual ambient processes and at the same time frees you from the need to deal with algorithmization. Changing some equations in a model or adding new equations do not require rebuilding the entire algorithm, and that considerably simplifies the study of how some or other processes influence solution results.

REFERENCE DATA

An actual electric network including power sources, consumption nodes, communication lines, connecting buses, etc. is presented by a loading equivalent diagram with the following parameters:

Table 0-1. The List of Needed Reference Data

Network Component	Equivalent Diagram	Parameters
Generator		Limits of active generation, $\cos\phi$, a cost of a power unit
Consumer		Active and reactive loads
Transmission Line	Pi-diagram	Resistance and reactance, conductance and capacitive susceptance of a shunt
Transformer	L-diagram	Resistance, reactance, and conductance of a shunt
Reactor		Conductance and susceptance of a shunt
Connecting Buses		Nominal and admissible voltage

Technological constraints proceed from admissible voltages of buses and allowable currents in transmission lines and transformers. Integral constraints proceed from constraints on the consumption of energy resources, on power exchange between different parts of a power pool, on electric power supply from external sources and electricity supply to external users.

We adjusted and studied the model using the Dushanbe – Vakhsh and Leninabad power systems as examples. Reference data are presented in Tables 5.1 – 5.4.

OPTIMIZATION CRITERION

The complexity of defining a single optimization criterion is in different economic conditions in republics of Central Asia. In some republics, the power industry belongs totally to the government; in other countries, it is partially private and is in the stage of restructuring. In our model, we proposed a criterion, which is able to achieve different goals without changing its own form.

$$\sum_t \sum_i P_{t,i}^{user} \times Price_i^{user} - \sum_t \sum_j P_{t,j}^{gen} \times Price_j^{gen} - \sum_t \sum_{duga} P_{t,duga}^{peret} \times Price_{duga}^{peret} \Rightarrow \max,$$

where

t = number of a time period (hour),

i = index of a consumer,

j = index of a power source,

$P_{t,i}^{user}$ = active consumption of the consumer i at the time t ,

$P_{t,j}^{gen}$ = active generation of the source j at the time t ,

$P_{t,duga}^{peret}$ = active transfer in a branch at the time t ,

$Price_i^{user}$ = tariff on consumption for the consumer i ,

$Price_i^{gen}$ = generation costs or the purchase price of a power unit of the generator j ,

$Price_{duga}^{peret}$ = tariff on electric power transit.

In such a form, the profit from sale and purchase of electric power becomes maximized. If we assign a single tariff for all consumers and a zero tariff on transit, the criterion transforms into minimized generation costs. If we assign the same generation cost for all sources, the criterion is limited to minimized losses in a network.

We may enter the power unit cost as the function of power, and we may differentiate the tariff on consumption for different time steps.

In our studies, we solved basically the problem of minimizing losses in a network.

MATHEMATICAL MODEL FORMULATION

To solve the problem stated we formally divided our electric power system into two groups of mathematical objects:

- 1) Mathematical objects, in which the integration of electric power flows occurs. We named these mathematical objects “nodes”. The attribute of the node is voltage.
- 2) Mathematical objects, which provide the transfer of numerical features of power between mathematical objects of the first type. We named these mathematical objects “arcs”. The attribute of the arc is current. There two types of arcs:
 - ✓ Simple arcs, in which the current value is constant at the beginning and at the end of an arc.
 - ✓ Transformer arcs, in which the current value changes from the beginning to the end depending on a transformation.

We set up the model’s equations in accordance with physical laws for alternating current in a three-phase system. Since all physical values in equations are complex, we wrote these equations twice: for the actual part and the imaginary part.

Generally, the time step is an hour. The sequence of time steps is ordered (the second time step follows the first, the first time step is before the second, etc). To show that a variable is time-dependant, we use the t symbol.

Nodes

Algorithmically, each node has a unique index.

Nodes may be of two types:

- Nodes with generation
- Nodes without generation

We made this division to optimize the calculation process. Variables (mathematical value determined by calculation) and parameters (mathematical value assigned primordially) that characterize physical processes in a node are actual and imaginary voltage, active and reactive generation (for nodes with generation), active and reactive consumption, and conductance and susceptance of a shunt.

Let us describe the equations used to conduct calculations in the mathematical model for each node.

- Kirchhoff's first law for actual and imaginary currents for the nodes with generation

$$\sum_{ij} I_{ij,t}^d + I_{ig,t}^d - I_{iu,t}^d - I_{ish,t}^d = 0,$$

$$\sum_{ij} I_{ij,t}^m + I_{ig,t}^m - I_{iu,t}^m - I_{ish,t}^m = 0,$$

where

i = name of the node for which we set up an equation,

ij = arc connecting the node i with the node j ,

$I_{ij,t}^d$ = actual current in the arc ij at the time t ,

$I_{ij,t}^m$ = imaginary current in the arc ij at the time t ,

$I_{ig,t}^d, I_{ig,t}^m$ = actual and imaginary currents of the generator connected with the node i , if any,

$I_{iu,t}^d, I_{iu,t}^m$ = actual and imaginary currents of the consumer connected with the node i ,

$I_{ish,t}^d, I_{ish,t}^m$ = actual and imaginary currents of leakage in the shunt connected with the node i .

- Kirchhoff's first law for actual and imaginary currents for the nodes without generation

$$\sum_{ij} I_{ij,t}^d - I_{iu,t}^d - I_{ish,t}^d = 0,$$

$$\sum_{ij} I_{ij,t}^m - I_{iu,t}^m - I_{ish,t}^m = 0.$$

We calculate currents of generation, consumption, and leakage as follows:

- Actual and imaginary currents of a generator

$$I_{ig,t}^d = \left(P_{g,t} \times U_{i,t}^d + Q_{g,t} \times U_{i,t}^m \right) / \left(\sqrt{3} \times U_{i,t}^2 \right),$$

$$I_{ig,t}^m = \left(P_{g,t} \times U_{i,t}^m - Q_{g,t} \times U_{i,t}^d \right) / \left(\sqrt{3} \times U_{i,t}^2 \right),$$

where

$P_{g,t}, Q_{g,t}$ = active and reactive generation at the time t,

$U_{i,t}^2 = U_{i,t}^{d^2} + U_{i,t}^{m^2}$ = squared module of voltage in the node i for the time t,

$U_{i,t}^d, U_{i,t}^m$ = actual and imaginary components of voltage.

- Actual and imaginary currents of a consumer

$$I_{iu,t}^d = \left(P_{u,t} \times U_{i,t}^d + Q_{u,t} \times U_{i,t}^m \right) / \left(\sqrt{3} \times U_{i,t}^2 \right),$$

$$I_{iu,t}^m = \left(P_{u,t} \times U_{i,t}^m - Q_{u,t} \times U_{i,t}^d \right) / \left(\sqrt{3} \times U_{i,t}^2 \right),$$

where

$P_{u,t}, Q_{u,t}$ = active and reactive power of the consumer connected with the node i for the time

t. If there is no consumption in a node, then, we accept as equal to zero.

- Actual and imaginary leakage current of a shunt

$$I_{ish,t}^d = \left(U_{i,t}^d \times g_i - U_{i,t}^m \times b_i \right) / \sqrt{3},$$

$$I_{ish,t}^m = \left(U_{i,t}^d \times b_i + U_{i,t}^m \times g_i \right) / \sqrt{3},$$

where

g_i = conductance of a shunt in the node i,

b_i = susceptance of a shunt in the node i.

For the nodes with generation, we write a ratio between active and reactive generation:

$$Q_{g,t} = tg\varphi \times P_{g,t}.$$

You may assign the nodes named balanced in the model such that the ratio will not be valid for these nodes. We entered the notion of generating nodes with assigned generation into the model.

Arcs

Algorithmically, each arc has a unique index. For each arc determining the structure of the electric power system, two paired associations are defined: *node-arc* as the beginning of the arc and *arc-node* as the end of the arc. The beginning and the end of the arc define positive direction of current.

We may name two types of arcs:

- Simple arc
- Transformer arc

The actual and imaginary current components are main variables characterizing physical processes in an arc.

We describe the equations used to conduct calculations in the mathematical model for each arc.

- Ohm's law for simple arcs:

$$\begin{aligned} U_{i,t}^d - U_{j,t}^d &= \sqrt{3} \times (I_{ij,t}^d \times r_{ij} - I_{ij,t}^m \times x_{ij}), \\ U_{i,t}^m - U_{j,t}^m &= \sqrt{3} \times (I_{ij,t}^d \times x_{ij} + I_{ij,t}^m \times r_{ij}), \end{aligned}$$

where

$U_{i,t}^d, U_{j,t}^d, U_{i,t}^m, U_{j,t}^m$ = actual and imaginary voltages at the ends of the arc ij for the time t,

r_{ij}, x_{ij} = resistance and reactance of the arc ij.

- Variation of actual and imaginary voltage and current on transformer arcs

$$\begin{aligned}
 U_{i,t}^d - U_{j,t}^d / \text{koef}_{-tr_{ij}} &= \sqrt{3} \times (I_{ij,t}^d \times r_{ij} - I_{ij,t}^m \times x_{ij}), \\
 U_{i,t}^m - U_{j,t}^m / \text{koef}_{-tr_{ij}} &= \sqrt{3} \times (I_{ij,t}^d \times x_{ij} + I_{ij,t}^m \times r_{ij}), \\
 I_{ij,t_k}^d / I_{ij,t_n}^d &= \text{koef}_{-tr_{ij}}, \\
 I_{ij,t_k}^m / I_{ij,t_n}^m &= \text{koef}_{-tr_{ij}},
 \end{aligned}$$

where

$\text{koef}_{-tr_{ij}}$ = transformation coefficient,

$I_{ij,t_k}^d, I_{ij,t_n}^m$ - current at the end and the beginning of a transformer arc..

We calculate transfers at the beginning and the end of an arc through the current variables obtained.

$Peretok_{ij,t}^d = \sqrt{3} \times (I_{ij}^d \times U_i^d + I_{ij}^m \times U_i^m)$ - active transfer at the beginning of the arc,

$Peretok_{ij,t}^d = \sqrt{3} \times (I_{ij}^d \times U_j^d + I_{ij}^m \times U_j^m)$ - active transfer at the end of the arc,

$Peretok_{ij,t}^d = \sqrt{3} \times (I_{ij}^d \times U_i^m - I_{ij}^m \times U_i^d)$ - reactive transfer at the beginning of the arc,

$Peretok_{ij,t}^d = \sqrt{3} \times (I_{ij}^d \times U_j^m - I_{ij}^m \times U_j^d)$ - reactive transfer at the end of the arc.

These equations are not included in the algorithmic model, and transfer values appear only in the output forms.

Constraints

The model assists in calculating the following variables:

$U_{i,t}^d$ = actual voltage component,

$U_{i,t}^m$ = imaginary voltage component,

$U_{i,t}^{\text{mod}}$ = voltage module,

$I_{ij,t}^d$ = actual current component,

$I_{ij,t}^m$ = imaginary current component,

$I_{ij,t}^{\text{mod}}$ = current module,

$P_{i,t}$ = active generation,

$Q_{i,t}$ = reactive generation,

W_i = generation in a generating node.

All variables except generation are defined for each time step. You may assign three types of constraints for each variable, each time step, each node, and each arc:

- 1) lower bound;
- 2) upper bound;
- 3) fixed value.

Besides, we enter in the model constraints in the form of equations

- for the limiting values of the voltage module in the nodes:

$$U_{i,t}^{\text{mod}} \leq 1.1 * U_i^{\text{nom}},$$

$$U_{i,t}^{\text{mod}} \geq 0.9 * U_i^{\text{nom}},$$

where: U_i^{nom} = rated voltage in a node.

The percentage deviation from the nominal (rated) voltage may vary.

- for generation at the stations with assigned generation:

$$W_g = \sum_t P_{g,t},$$

where g is the index of the station with limited energy, such stations in the model are assigned in the corresponding set.

Calculation will result in a the solution found within strictly assigned limits.

CALCULATION EXAMPLES AND THE RESULTS VALIDITY

As a test problem, we calculated an optimal load for generators of the Dushanbe-Vakhsh power System (DVPS, SSHC *Barki Tochik*) that includes:

- 33 nodes (total),
- 8 nodes with generating sources (2 of them are balancing),
- 13 nodes with non-zero consumption,
- 35 arcs, including:
 - ◆ 17 simple arcs,
 - ◆ 18 transformer arcs.

The loading diagram is shown in Figure 1.

The DVPS power grids supply power for the southern regions of Tajikistan and Surkhandarya Oblast of Uzbekistan. The Surkhandarya load is included in the consumption of the 521 node. The connection with the Central Asian Power Pool is presented as a fixed generation and the load of the 520 node.

This system contains two hydropower plants: Nurek HPP (nodes 251, 252, 253, 257, and 259), and Baipazin HPP (nodes 31 and 32). The hydropower stations are a part of the Vakhsh cascade, and thus, they are connected with each other through water consumption. In the model this link is expressed by an equation connecting the generation of these stations:

$$W_{251} + W_{252} + W_{253} + W_{258} + W_{259} = 4 \times (W_{31} + W_{32})$$

We did not enter constraints on the consumption of energy resources, because we assumed that the system did not have sources of limited energy. The parameters of the loading diagram are given in Tables 1 –4.

DVPS EQUIVALENT DIAGRAM

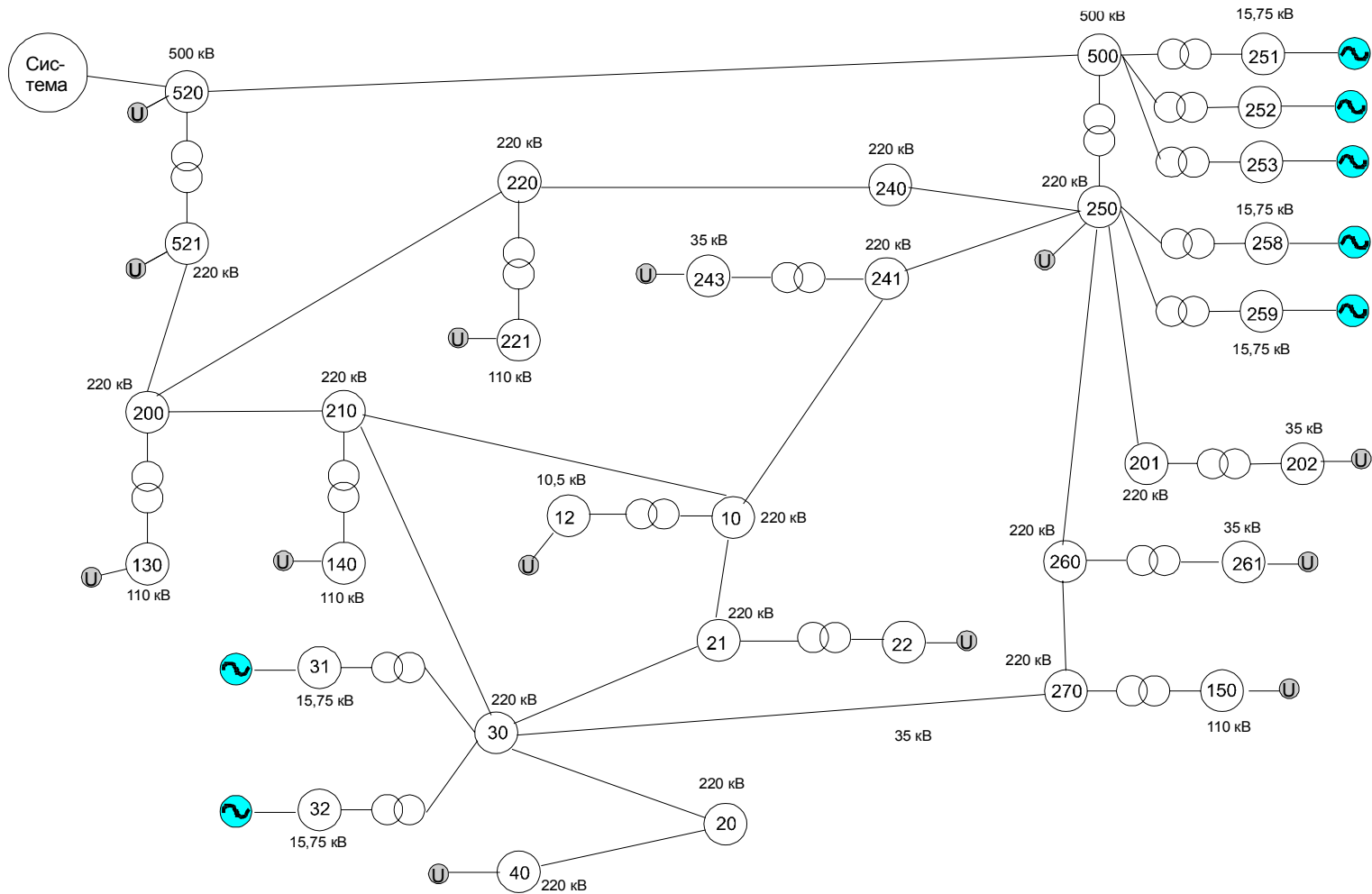


Figure 1. Loading Diagram

Table 1. Node Data

Node	Rated Voltage	Generation Available	Node	Rated Voltage	Generation Available
	kV			kV	
10	220		32	15.75	да
12	10.5		40	220	
250	220		201	220	
251	15.75	Yes	202	35	
252	15.75	Yes	221	110	
253	15.75	Yes	130	110	
258	15.75	Yes	140	110	
259	15.75	Yes	200	220	
20	220		210	220	
21	220		220	220	
22	35		240	220	
260	220		241	220	
261	35		243	35	
270	220		500	500	
150	110		520	500	Yes
30	220		521	220	
31	15.75	Yes			

Table 2. Arc Data

Arc	r	x	b (sm)	Transformation Coefficient
250_241	0.28	1.2	-8.2	
250_240	0.28	1.2	-8.2	
241_243	6.65	169	0	0.167
500_251	0.72	43.9	0	0.03
500_252	0.72	43.8	0	0.03
500_253	0.72	43.5	0	0.03
250_258	0.16	8.35	0	0.065
250_259	0.32	16.7	0	0.065
500_250	0.48	28.8	0	0.469
250_201	2.4	9.3	-60	
250_260	2.44	10.7	-65.7	
260_270	1.76	7.72	-47.5	
260_261	11.44	276	0	0.167
201_202	5.72	138	0	0.167
30_31	0.38	14.6	0	0.065
30_32	0.38	14.6	0	0.065

30_20	0.85	3.67	-23.6	
30_21	1.03	4.43	-28.5	
30_210	3.77	21	-141	
30_270	3	16.8	-108	
200_220	2.6	10.1	-64.8	
21_22	7.94	165	0	0.175
520_521	0.255	14.75	0	0.486
10_210	3.41	13.5	-86.5	
500_520	1.37	16.82	-849	
10_241	4.92	19	-122	
200_521	5.1	20	-129	
220_240	5.2	20.3	-130	
220_221	0.5	22.82	0	0.55
200_210	6.24	24.5	-158	
20_40	6.3	24.6	-159	
200_130	0.51	25.24	0	0.55
210_140	0.5	26.66	0	0.55
270_150	1.265	50.65	0	0.55
10_12	9.4	269	0	0.043

Table 3. Active and Reactive Consumption in Nodes for Each Hour

Hour\ Node	Consumption of Active Power in Nodes													
	12	22	261	150	40	202	221	130	140	243	520	521	250	
t1	20	15	5	90	100	1	50	100	165	15	130	611	0	
t2	20	15	5	90	100	1	55	105	167	15	130	614	0	
t3	20	15	5	90	100	1	60	105	168	15	130	624	0	
t4	20	15	5	90	100	1	70	180	192	15	192	642	0	
t5	25	25	10	95	100	1	120	195	202	20	195	677	88	
t6	25	25	10	95	175	1	110	195	197	20	293	664	81	
t7	25	35	15	95	175	1	115	195	191	20	380	669	78	
t8	20	25	15	95	140	1	100	180	183	20	165	676	50	
t9	20	15	15	95	80	1	80	160	170	20	155	660	23	
t10	18	11	10	80	80	1	70	150	165	15	150	629	24	
t11	18	11	10	80	95	1	70	150	175	15	145	624	32	
t12	18	11	10	90	95	1	60	160	190	15	145	618	32	
t13	18	11	10	75	95	1	65	160	190	15	145	624	30	
t14	18	11	10	80	95	1	65	170	200	15	140	621	38	
t15	18	11	10	100	95	1	70	170	195	15	140	618	32	
t16	18	15	10	125	95	1	85	185	195	15	140	624	50	
t17	18	18	20	120	190	1	110	195	195	20	162	671	85	
t18	25	25	20	120	190	1	120	200	200	25	291	705	83	

t19	25	25	20	120	180	1	130	205	205	25	315	716	91
t20	25	25	15	120	180	1	130	200	199	25	296	707	87
t21	25	25	15	110	190	1	120	195	194	25	303	693	84
t22	25	18	15	110	190	1	90	160	150	25	160	673	14
t23	23	18	10	100	145	1	80	150	165	20	160	641	14
t24	20	18	5	95	125	1	70	150	165	15	150	638	14
Consumption of Reactive Power in Nodes													
Hour \ Node	12	22	261	150	40	202	221	130	140	243	520	521	250
t1	9	7	2	43	25	0.5	24	48	80	7	42	278	0
t2	9	7	2	43	25	0.5	26	165	81	7	42	279	0
t3	9	7	2	43	25	0.5	29	51	81	7	42	275	0
t4	9	7	2	43	25	0.5	34	87	93	7	42	291	0
t5	12	12	5	46	25	0.5	58	94	98	9	28	308	29
t6	12	12	5	46	50	0.5	53	94	95	9	28	302	29
t7	12	17	7	46	50	0.5	55	94	92	9	21	295	20
t8	9	12	7	46	40	0.5	48	87	88	9	21	298	0
t9	9	7	7	46	75	0.5	38	77	82	9	21	300	0
t10	8	5	5	39	75	0.5	34	72	80	7	28	292	0
t11	8	5	5	39	50	0.5	34	72	85	7	28	296	0
t12	8	5	5	43	50	0.5	29	77	92	7	28	298	0
t13	8	5	5	36	50	0.5	31	77	92	7	28	291	0
t14	8	5	5	39	50	0.5	31	82	97	7	28	295	0
t15	8	5	5	48	50	0.5	34	82	94	7	35	299	0
t16	8	7	5	60	50	0.5	41	89	94	7	28	320	0
t17	8	8	9	58	75	0.5	53	94	94	9	14	317	27
t18	12	12	9	58	75	0.5	58	97	97	12	0	326	30
t19	12	12	9	58	75	0.5	63	99	97	12	0	319	30
t20	13	12	7	58	75	0.5	63	97	96	12	7	314	29
t21	12	12	7	53	75	0.5	58	94	94	12	7	305	24
t22	12	8	7	53	75	0.5	43	77	72	12	21	305	0
t23	11	8	5	48	45	0.5	38	72	80	9	28	294	0
t24	9	8	2	46	35	0.5	34	72	80	7	35	293	0

Table 4 Generator Data

Node	Cost	tgφ	Minimum Capacity	Maximum Capacity
	c.u./MWh		MWh	MWh
251 (balancing node)	1	0.391	0	667
252	1	0.15	0	667
253	1	0.15	0	667
258	1	0	300	667
259	1	0	0	333
31	1	0.4	0	300
32	1	0.4	0	300
520 (generation is fixed)	10		0	2000

Tables 5 –9 show the results of calculations

Table 5. Node Voltage

Volt./Hour	t1	t2	t3	t4	t5	t6	t7	t8
10	221.97	223.58	222.93	223.23	222.3	222.26	222.25	223.35
12	8.94	9.02	8.99	9	8.72	8.72	8.72	9.01
250	227.65	230.83	228.72	230.83	230.83	230.83	230.83	230.83
251	15.14	15.82	15.22	15.74	16.17	16.19	16.27	15.91
252	14.85	15.18	14.92	15.18	15.32	15.33	15.34	15.23
253	14.85	15.18	14.92	15.18	15.32	15.33	15.34	15.23
258	14.79	15	14.86	15	15	15	15	15
259	14.8	15	14.87	15	15	15	15	15
20	223.74	225.66	224.82	225.66	225.84	223.93	223.54	225.06
21	224.34	226.25	225.41	226.25	226.26	225.28	224.69	225.98
22	38.15	38.5	38.35	38.5	37.69	37.51	36.44	37.64
260	225.05	227.89	226.14	227.87	227.68	227.38	227.13	227.46
261	37.11	37.59	37.3	37.59	36.84	36.78	36.18	36.24
270	223.22	225.81	224.32	225.78	225.6	225.09	224.79	225.35
150	116.25	117.77	116.89	117.75	117.15	116.84	116.66	117
30	224.56	226.47	225.63	226.47	226.65	225.67	225.28	226.37
31	14.79	14.93	14.87	14.94	15	14.99	14.98	14.99
32	14.79	14.93	14.87	14.94	15	14.99	14.98	14.99
40	217.78	219.75	218.88	219.75	219.94	212.14	211.73	215.93
201	227.68	230.86	228.75	230.86	230.86	230.86	230.86	230.86
202	37.97	38.5	38.15	38.5	38.5	38.5	38.5	38.5
221	121	120.28	121	120.11	116.99	117.6	117.26	118.51
130	118.72	108.54	118.9	114.79	113.08	113.24	113.06	114.46

140	114.09	114.31	114.5	112.86	111.67	111.92	112.2	113.44
200	222.01	219.1	222.72	220.72	218.91	219.18	218.87	220.16
210	219.12	219.65	220	219.16	217.99	217.92	217.9	219.34
220	222.66	221.6	223.23	222.21	219.57	220.05	219.69	221.03
240	227.38	230.33	228.43	230.36	230.21	230.23	230.21	230.29
241	227.27	230.37	228.34	230.34	230.27	230.27	230.27	230.33
243	36.94	37.47	37.12	37.47	37.13	37.13	37.13	37.14
500	491.87	502.79	494.45	501.94	506.37	506.52	506.45	503.4
520	484.5	493.07	487.08	492.23	495.27	495.31	494.29	492.83
521	229.64	232.81	230.88	232.61	233.44	233.56	233.16	232.68
Volt./Hour	t9	t10	t11	t12	t13	t14	t15	t16
10	223.3	223.81	223.59	223.09	223.12	222.72	222.89	222.7
12	9	9.1	9.09	9.07	9.07	9.05	9.06	9.05
250	230.83	230.83	230.83	230.73	230.83	230.83	230.83	230.83
251	15.92	15.76	15.74	15.78	15.76	15.87	15.87	16.06
252	15.22	15.17	15.16	15.17	15.17	15.19	15.21	15.26
253	15.22	15.17	15.16	15.17	15.17	15.19	15.21	15.26
258	15	15	15	14.99	15	15	15	15
259	15	15	15	15	15	15	15	15
20	221.9	222.37	223.22	223.22	223.22	223.22	223.22	223.35
21	223.28	223.81	224.29	224.29	224.29	224.29	224.29	224.36
22	38	38.41	38.5	38.5	38.5	38.5	38.5	38.19
260	226.57	227.17	227.28	227.03	227.41	227.3	226.87	226.32
261	36.08	36.75	36.77	36.72	36.79	36.77	36.7	36.6
270	223.83	224.72	224.92	224.56	225.14	224.95	224.22	223.26
150	116.1	117.84	117.95	117.03	118.56	117.97	115.95	113.1
30	223.49	223.96	224.44	224.44	224.44	224.44	224.44	224.57
31	14.75	14.76	14.77	14.79	14.78	14.8	14.81	14.86
32	14.75	14.76	14.77	14.79	14.78	14.8	14.81	14.86
40	210.63	211.13	214.49	214.49	214.49	214.49	214.49	214.63
201	230.86	230.86	230.86	230.76	230.86	230.86	230.86	230.86
202	38.5	38.5	38.5	38.48	38.5	38.5	38.5	38.5
221	120.09	120.78	120.71	121	120.81	120.56	120.3	119.19
130	116.19	117.04	116.94	116.28	116.26	115.46	115.48	114.22
140	113.94	114.55	113.9	112.76	112.76	111.87	112.32	112.12
200	221.65	222.4	222.23	221.8	221.77	221.12	221.17	220.07
210	219.2	219.9	219.59	218.82	218.82	218.16	218.42	218.1
220	222.65	223.41	223.29	223.23	223.12	222.67	222.55	221.4
240	230.39	230.43	230.42	230.33	230.41	230.39	230.38	230.31
241	230.33	230.38	230.37	230.24	230.34	230.31	230.32	230.31
243	37.14	37.47	37.47	37.45	37.47	37.46	37.46	37.46
500	503.85	502.34	502.06	502.36	502.33	503.06	503.45	505
520	493.81	492.87	492.55	492.87	492.92	493.03	493.63	494.24

521	233.28	233.1	232.92	232.99	233.09	233.01	233.22	233.05
Volt./Hour	t17	t18	t19	t20	t21	t22	t23	t24
10	222.21	221.16	221.02	221.2	221.7	223.83	224.23	224.57
12	9.03	8.67	8.66	8.6	8.69	8.8	8.9	9.06
250	230.83	230.83	230.83	230.83	230.83	230.83	230.83	230.75
251	16.38	16.68	16.62	16.52	16.32	15.81	15.56	15.39
252	15.38	15.45	15.47	15.45	15.4	15.22	15.15	15.1
253	15.38	15.45	15.47	15.45	15.4	15.22	15.15	15.1
258	15	15	15	15	15	15	15	15
259	15	15	15	15	15	15	15	15
20	221.14	220.41	220.46	220.61	221.08	222.37	225.29	226.04
21	223.23	222.37	222.33	222.49	223.03	224.45	226.46	226.91
22	37.81	36.97	36.96	36.99	37.09	38.03	38.4	38.48
260	225.83	225.6	225.59	225.79	226.21	226.6	227.58	227.91
261	35.33	35.29	35.29	35.94	36.02	36.09	36.82	37.6
270	222.7	222.32	222.3	222.48	223.21	223.87	225.44	225.91
150	113.17	112.94	112.92	113.04	114.44	114.84	116.68	117.33
30	223.49	222.77	222.73	222.89	223.42	224.7	226.71	227.16
31	14.88	14.85	14.84	14.85	14.88	14.92	15	15
32	14.88	14.85	14.84	14.85	14.88	14.92	15	15
40	205.38	204.58	205.08	205.26	205.31	206.73	215.39	218.1
201	230.86	230.86	230.86	230.86	230.86	230.86	230.86	230.78
202	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.49
221	117.61	116.64	116	116.17	117.01	119.73	120.49	121
130	113.22	112.3	111.95	112.4	113.13	116.38	117.21	117.4
140	111.64	110.63	110.44	110.81	111.47	115.6	115.2	115.42
200	219.15	218.05	217.8	218.21	218.99	221.98	222.7	223.01
210	217.29	216.11	215.88	216.25	217	220.47	221.01	221.38
220	220.05	218.96	218.48	218.77	219.62	222.59	223.37	223.8
240	230.24	230.17	230.14	230.16	230.21	230.38	230.43	230.37
241	230.26	230.18	230.17	230.18	230.21	230.34	230.38	230.35
243	37.13	36.64	36.64	36.64	36.65	36.67	37.15	37.47
500	508.44	510.3	510.65	510.1	508.52	503.6	501.4	500.05
520	496.69	496.54	498.01	498.15	497.69	494.59	493.5	493.37
521	233.96	233.58	234.26	234.44	234.48	233.57	233.38	233.39

Table 6. Active Generation

Node/Hour	t1	t2	t3	t4	t5	t6	t7	t8
251	228.93	227.21	228.53	323.84	383.76	405.7	439.4	347.12
252	235.86	243.25	235.88	331.13	389.1	408.91	439.17	354.16
253	235.89	243.41	235.94	331.28	389.37	409.2	439.48	354.36
258	300	300	300	300	300	300	300	300
259	0	0	0	0	0	0	0	0
31	115.93	121.92	117.74	128.43	158.46	198.92	204.27	169.32
32	115.92	121.92	117.74	128.44	158.46	198.92	204.27	169.32
520	83	76	111	0	0	0	0	0
Node/hour	t9	t10	t11	t12	t13	t14	t15	t16
251	270.87	253.37	267.35	244.74	256	241.81	267.94	281.51
252	284.46	266.25	278.9	258.66	268.63	257.42	281.17	296.04
253	284.62	266.38	279.03	258.79	268.76	257.56	281.31	296.23
258	300	300	300	300	300	300	300	300
259	0	0	0	0	0	0	0	0
31	130.47	118.42	106.88	120.51	112.55	122.63	129.82	154.28
32	130.47	118.42	106.88	120.52	112.55	122.63	129.82	154.28
520	112	97	104	159	138	180	104	97
Node/hour	t17	t18	t19	t20	t21	t22	t23	t24
251	362.15	428.82	450.53	435.24	425.03	290.33	282.44	253.48
252	371.13	430.75	449.67	436.21	426.72	300.68	290.09	259.88
253	371.41	431.15	450.12	436.56	427.04	300.82	290.19	259.94
258	300	300	300	300	300	300	300	300
259	0	0	0	0	0	0	0	0
31	215.97	225.43	222.59	219.03	217.93	190.41	157.44	139.29
32	215.98	225.43	222.58	219.03	217.93	190.41	157.44	139.29
520	0	0	0	0	0	83	69	131

Table 7. Reactive Generation

Node/hour	t1	t2	t3	t4	t5	t6	t7	t8
251	146.01	297.18	151.36	272.84	407.72	415.34	449.28	329.67
252	35.38	36.49	35.38	49.67	58.37	61.34	65.88	53.12
253	35.38	36.51	35.39	49.69	58.4	61.38	65.92	53.15
258	0	0	0	0	0	0	0	0
259	0	0	0	0	0	0	0	0
31	46.37	48.77	47.1	51.37	63.38	79.57	81.71	67.73
32	46.37	48.77	47.1	51.37	63.38	79.57	81.71	67.73
520	194	194	194	208	208	208	180	180
Node/hour	t9	t10	t11	t12	t13	t14	t15	t16
251	323.82	277.61	273.01	284.67	276.66	312.72	309.89	370.24
252	42.67	39.94	41.83	38.8	40.3	38.61	42.17	44.41
253	42.69	39.96	41.85	38.82	40.31	38.63	42.2	44.43
258	0	0	0	0	0	0	0	0
259	0	0	0	0	0	0	0	0
31	52.19	47.37	42.75	48.21	45.02	49.05	51.93	61.71
32	52.19	47.37	42.75	48.21	45.02	49.05	51.93	61.71
520	166	166	166	166	166	152	180	180
Node/hour	t17	t18	t19	t20	t21	t22	t23	t24
251	471.08	583.61	554.24	516.95	444.56	283.87	207.5	151.19
252	55.67	64.61	67.45	65.43	64.01	45.1	43.51	38.98
253	55.71	64.67	67.52	65.48	64.06	45.12	43.53	38.99
258	0	0	0	0	0	0	0	0
259	0	0	0	0	0	0	0	0
31	86.39	90.17	89.03	87.61	87.17	76.16	62.97	55.72
32	86.39	90.17	89.03	87.61	87.17	76.16	62.98	55.72
520	180	152	194	208	221	208	221	249

Table 8. Transfer at the Beginning of an Arc

Arc/hour	t1	t2	t3	t4	t5	t6	t7	t8
250_241	120.58	120.24	122.3	141.55	147.35	145.46	145.52	138.64
250_240	135.26	138.56	141.77	180.24	205.22	202.74	208.82	190.67
241_243	15.04	15.04	15.04	15.04	20.06	20.06	20.06	20.06
500_251	-228.72	-226.84	-228.32	-323.37	-382.98	-404.87	-438.44	-346.53
500_252	-235.69	-243.08	-235.71	-330.82	-388.67	-408.44	-438.63	-353.8
500_253	-235.72	-243.24	-235.77	-330.97	-388.94	-408.72	-438.94	-354
250_258	-299.72	-299.73	-299.72	-299.73	-299.73	-299.73	-299.73	-299.73
250_259	0	0	0	0	0	0	0	0
500_250	37.47	34.91	45.34	105.99	212.51	199.07	206.18	159.16
250_201	1	1	1	1	1	1	1	1
250_260	80.33	74.78	79.95	82.85	70.47	68.42	72.37	78.45

260_270	74.95	69.42	74.58	77.43	60.09	58.01	56.88	62.96
260_261	5.01	5.01	5.01	5.01	10.03	10.03	15.07	15.07
201_202	1	1	1	1	1	1	1	1
30_31	-115.81	-121.79	-117.62	-128.3	-158.25	-198.6	-203.92	-169.08
30_32	-115.81	-121.79	-117.62	-128.3	-158.25	-198.59	-203.92	-169.08
30_20	101.6	101.57	101.58	101.57	101.57	180.25	180.27	143.24
30_21	15.05	15.05	15.05	15.05	25.15	25.15	35.31	25.15
30_210	99.37	105.85	102.65	126.85	154.3	154.19	153.52	137.15
30_270	15.6	21.12	15.96	13.13	35.5	37.6	38.74	32.63
200_220	-82.88	-80.67	-79.22	-105.95	-79.75	-87.41	-88.17	-86
21_22	15.05	15.05	15.05	15.05	25.13	25.13	35.28	25.13
520_521	613	621.41	632.89	682.64	747.84	723.93	722.71	725.45
10_210	84.15	83.68	85.84	104.52	100.07	98.21	98.27	96.76
500_520	662.67	678.25	654.47	879.16	948.08	1022.96	1109.82	895.18
10_241	-104.26	-103.79	-105.95	-124.62	-125.24	-123.38	-123.44	-116.86
200_521	-0.69	-4.42	-7.47	-38.23	-67.37	-56.61	-50.45	-46.77
220_240	-133.27	-136.12	-139.6	-176.62	-200.3	-197.99	-203.78	-186.53
220_221	50.03	55.04	60.05	70.06	120.2	110.16	115.18	100.13
200_210	-16.57	-20.41	-18.46	-36.28	-48.44	-51.54	-56.94	-47.71
20_40	101.41	101.39	101.4	101.39	101.38	179.64	179.66	142.86
200_130	100.13	105.5	105.15	180.47	195.57	195.56	195.57	180.47
210_140	165.39	167.4	168.4	192.54	202.61	197.58	191.54	183.48
270_150	90.28	90.27	90.28	90.27	95.31	95.31	95.31	95.31
10_12	20.1	20.1	20.1	20.1	25.18	25.18	25.18	20.1
Arc/hour	t9	t10	t11	t12	t13	t14	t15	t16
250_241	128.52	120.3	132.38	132.46	135.57	135.73	134.24	129.75
250_240	168.44	159.26	160.55	156.22	161.06	161.82	165.98	175.79
241_243	20.06	15.04	15.04	15.04	15.04	15.04	15.04	15.04
500_251	-270.42	-253	-266.97	-244.37	-255.63	-241.4	-267.51	-280.96
500_252	-284.23	-266.05	-278.68	-258.47	-268.43	-257.23	-280.94	-295.79
500_253	-284.39	-266.18	-278.81	-258.6	-268.55	-257.37	-281.09	-295.98
250_258	-299.73	-299.73	-299.73	-299.73	-299.73	-299.73	-299.73	-299.73
250_259	0	0	0	0	0	0	0	0
500_250	95.71	70.99	114.15	106.33	109.82	114.47	118.72	139.69
250_201	1	1	1	1	1	1	1	1
250_260	74.38	66.09	87.86	84.3	81.84	77.55	85.12	82.74
260_270	58.81	55.67	77.33	73.77	71.36	67.09	74.56	72.11
260_261	15.07	10.03	10.03	10.03	10.03	10.03	10.03	10.03
201_202	1	1	1	1	1	1	1	1
30_31	-130.32	-118.3	-106.78	-120.39	-112.45	-122.5	-129.68	-154.08
30_32	-130.32	-118.3	-106.78	-120.39	-112.44	-122.5	-129.68	-154.08
30_20	81.93	81.92	96.78	96.78	96.78	96.78	96.78	96.78
30_21	15.05	11.03	11.03	11.03	11.03	11.03	11.03	15.05
30_210	126.79	118.83	102.56	116.15	112.98	123.8	125.4	142.32

30_270	36.87	24.82	3.19	16.82	4.1	13.4	26.15	54
200_220	-84.8	-86.01	-87.23	-92.99	-92.67	-93.33	-92.36	-86.72
21_22	15.05	11.02	11.02	11.02	11.02	11.02	11.02	15.05
520_521	696.98	658.15	666.24	666.45	672.94	678.94	671.75	686.73
10_210	86.83	85.79	97.61	97.64	100.67	100.78	99.34	94.92
500_520	743.32	714.24	710.3	655.1	682.79	641.53	710.82	733.04
10_241	-106.94	-103.88	-115.69	-115.72	-118.75	-118.86	-117.42	-113
200_521	-34.63	-27.12	-40.18	-46.24	-46.69	-55.48	-51.27	-59.9
220_240	-165.27	-156.46	-157.7	-153.5	-158.17	-158.86	-162.88	-172.22
220_221	80.08	70.06	70.06	60.05	65.05	65.05	70.06	85.09
200_210	-40.93	-37.19	-22.9	-21.13	-21	-21.59	-26.78	-38.88
20_40	81.71	81.7	96.58	96.58	96.58	96.58	96.58	96.58
200_130	160.36	150.31	150.31	160.36	160.36	170.41	170.41	185.5
210_140	170.42	165.39	175.44	190.53	190.53	200.6	195.56	195.56
270_150	95.32	80.22	80.22	90.28	75.19	80.22	100.35	125.58
10_12	20.1	18.08	18.08	18.08	18.08	18.08	18.08	18.08
Arc/hour	t17	t18	t19	t20	t21	t22	t23	t24
250_241	135.56	149.08	151.72	149.47	147.6	131.75	131.36	125.23
250_240	195.38	210.1	217.86	214.83	207.69	173.62	166.66	159.49
241_243	20.06	25.11	25.11	25.11	25.11	25.11	20.06	15.04
500_251	-361.29	-427.59	-449.33	-434.15	-424.11	-289.91	-282.11	-253.24
500_252	-370.74	-430.23	-449.11	-435.68	-426.21	-300.42	-289.85	-259.68
500_253	-371.03	-430.63	-449.56	-436.03	-426.53	-300.57	-289.95	-259.74
250_258	-299.73	-299.73	-299.73	-299.73	-299.73	-299.73	-299.73	-299.73
250_259	0	0	0	0	0	0	0	0
500_250	197.79	222.76	240.82	228.81	213.7	103.19	94.73	79.7
250_201	1	1	1	1	1	1	1	1
250_260	80.36	79.03	78.66	75.95	72.9	82.45	81.37	79.66
260_270	59.57	58.21	57.83	60.23	57.27	66.83	70.91	74.28
260_261	20.12	20.12	20.12	15.07	15.07	15.07	10.03	5.01
201_202	1	1	1	1	1	1	1	1
30_31	-215.58	-225	-222.17	-218.62	-217.53	-190.11	-157.23	-139.13
30_32	-215.58	-225	-222.16	-218.62	-217.53	-190.1	-157.23	-139.13
30_20	197.06	197.11	186.45	186.44	197.06	196.97	148.54	127.53
30_21	18.07	25.15	25.15	25.15	25.15	18.07	18.07	18.07
30_210	154.51	164.81	169.43	164.76	159.2	121.15	118.11	111.35
30_270	61.52	62.92	63.3	60.89	53.64	44.02	29.74	21.32
200_220	-80.4	-84.29	-81.63	-78.81	-82.11	-79.82	-83.17	-86.26
21_22	18.07	25.14	25.14	25.14	25.14	18.07	18.06	18.06
520_521	738.42	768.02	785.16	774.44	753.76	707.08	672.77	671.2
10_210	95.6	96.63	99.19	97.01	95.28	80.05	86.69	88.7
500_520	905.27	1065.7	1107.18	1077.06	1063.15	787.71	767.18	692.97
10_241	-113.68	-121.81	-124.37	-122.2	-120.45	-105.22	-109.83	-108.8
200_521	-63.89	-59.18	-64.93	-63.33	-57	-31.72	-29.72	-31.24

220_240	-190.91	-204.88	-212.23	-209.38	-202.68	-170.27	-163.62	-156.72
220_221	110.16	120.2	130.23	130.23	120.2	90.1	80.08	70.06
200_210	-51.28	-57.13	-59.09	-58.47	-56.46	-48.82	-37.42	-32.81
20_40	196.23	196.28	185.7	185.69	196.24	196.15	148.13	127.23
200_130	195.56	200.6	205.64	200.6	195.56	160.36	150.31	150.31
210_140	195.57	200.61	205.64	199.6	194.57	150.31	165.38	165.38
270_150	120.53	120.53	120.53	120.53	110.44	110.43	100.35	95.31
10_12	18.08	25.18	25.18	25.19	25.18	25.17	23.14	20.1

Table 9. Transfer at the End of an Arc

Arc/hour	t1	t2	t3	t4	t5	t6	t7	t8
250_241	120.49	120.14	122.21	141.43	147.21	145.32	145.38	138.52
250_240	135.16	138.43	141.66	180.06	204.97	202.5	208.57	190.46
241_243	15	15	15	15	20	20	20	20
500_251	-228.93	-227.21	-228.53	-323.84	-383.76	-405.7	-439.4	-347.12
500_252	-235.86	-243.25	-235.88	-331.13	-389.1	-408.91	-439.17	-354.16
500_253	-235.89	-243.41	-235.94	-331.28	-389.37	-409.2	-439.48	-354.36
250_258	-300	-300	-300	-300	-300	-300	-300	-300
250_259	0	0	0	0	0	0	0	0
500_250	37.44	34.85	45.31	105.91	212.31	198.88	205.99	159.04
250_201	1	1	1	1	1	1	1	1
250_260	79.96	74.43	79.59	82.44	70.12	68.04	71.95	78.03
260_270	74.71	69.18	74.35	77.16	59.89	57.8	56.66	62.75
260_261	5	5	5	5	10	10	15	15
201_202	1	1	1	1	1	1	1	1
30_31	-115.93	-121.92	-117.74	-128.43	-158.46	-198.92	-204.27	-169.32
30_32	-115.92	-121.92	-117.74	-128.44	-158.46	-198.92	-204.27	-169.32
30_20	101.41	101.39	101.4	101.39	101.38	179.64	179.66	142.86
30_21	15.05	15.05	15.05	15.05	25.13	25.13	35.28	25.13
30_210	98.5	104.79	101.73	125.41	152.19	152.16	151.53	135.55
30_270	15.57	21.09	15.93	13.11	35.42	37.52	38.65	32.56
200_220	-83.24	-81.08	-79.55	-106.55	-80.1	-87.83	-88.6	-86.39
21_22	15	15	15	15	25	25	35	25
520_521	612.43	620.78	632.29	681.93	746.99	723.13	721.92	724.67
10_210	83.61	83.07	85.29	103.65	99.22	97.38	97.44	95.99
500_520	660	675.41	651.89	874.64	942.84	1016.93	1102.71	890.45
10_241	-105.45	-105.11	-107.18	-126.39	-127.14	-125.25	-125.31	-118.45
200_521	-1.43	-6.78	-8.29	-39.93	-69.99	-59.13	-52.92	-48.67
220_240	-135.16	-138.43	-141.66	-180.06	-204.97	-202.5	-208.57	-190.46
220_221	50	55	60	70	120	110	115	100
200_210	-16.72	-20.46	-18.61	-36.52	-48.8	-51.97	-57.44	-48.05
20_40	100	100	100	100	100	175	175	140

200_130	100	105	105	180	195	195	195	180
210_140	165	167	168	192	202	197	191	183
270_150	90	90	90	90	95	95	95	95
10_12	20	20	20	20	25	25	25	20
Arc/hour	t9	t10	t11	t12	t13	t14	t15	t16
250_241	128.41	120.21	132.27	132.35	135.45	135.61	134.12	129.64
250_240	168.28	159.12	160.41	156.08	160.92	161.67	165.83	175.61
241_243	20	15	15	15	15	15	15	15
500_251	-270.87	-253.37	-267.35	-244.74	-256	-241.81	-267.94	-281.51
500_252	-284.46	-266.25	-278.9	-258.66	-268.63	-257.42	-281.17	-296.04
500_253	-284.62	-266.38	-279.03	-258.79	-268.76	-257.56	-281.31	-296.23
250_258	-300	-300	-300	-300	-300	-300	-300	-300
250_259	0	0	0	0	0	0	0	0
500_250	95.62	70.92	114.07	106.25	109.74	114.38	118.62	139.56
250_201	1	1	1	1	1	1	1	1
250_260	73.87	65.7	87.36	83.8	81.39	77.12	84.59	82.14
260_270	58.53	55.44	77.04	73.48	71.1	66.84	74.24	71.75
260_261	15	10	10	10	10	10	10	10
201_202	1	1	1	1	1	1	1	1
30_31	-130.47	-118.42	-106.88	-120.51	-112.55	-122.63	-129.82	-154.28
30_32	-130.47	-118.42	-106.88	-120.52	-112.55	-122.63	-129.82	-154.28
30_20	81.71	81.7	96.58	96.58	96.58	96.58	96.58	96.58
30_21	15.05	11.02	11.02	11.02	11.02	11.02	11.02	15.05
30_210	125.53	117.72	101.68	115.01	111.89	122.48	124.07	140.64
30_270	36.78	24.77	3.18	16.8	4.09	13.38	26.11	53.83
200_220	-85.19	-86.4	-87.63	-93.45	-93.12	-93.8	-92.82	-87.13
21_22	15	11	11	11	11	11	11	15
520_521	696.25	657.49	665.57	665.77	672.26	678.24	671.05	685.98
10_210	86.17	85.16	96.84	96.84	99.83	99.9	98.49	94.11
500_520	739.98	711.15	707.24	652.45	679.94	638.94	707.75	729.73
10_241	-108.34	-105.17	-117.23	-117.31	-120.41	-120.58	-119.09	-114.6
200_521	-36.25	-28.49	-41.57	-47.77	-48.26	-57.24	-53.05	-61.98
220_240	-168.28	-159.12	-160.41	-156.08	-160.92	-161.67	-165.83	-175.61
220_221	80	70	70	60	65	65	70	85
200_210	-41.28	-37.49	-23.08	-21.32	-21.19	-21.79	-27	-39.18
20_40	80	80	95	95	95	95	95	95
200_130	160	150	150	160	160	170	170	185
210_140	170	165	175	190	190	200	195	195
270_150	95	80	80	90	75	80	100	125
10_12	20	18	18	18	18	18	18	18
Arc / Hour	t17	t18	t19	t20	t21	t22	t23	t24
250_241	135.43	148.92	151.56	149.31	147.45	131.64	131.25	125.13
250_240	195.15	209.84	217.57	214.56	207.44	173.45	166.51	159.35
241_243	20	25	25	25	25	25	20	15

500_251	-362.15	-428.82	-450.53	-435.24	-425.03	-290.33	-282.44	-253.48
500_252	-371.13	-430.75	-449.67	-436.21	-426.72	-300.68	-290.09	-259.88
500_253	-371.41	-431.15	-450.12	-436.56	-427.04	-300.82	-290.19	-259.94
250_258	-300	-300	-300	-300	-300	-300	-300	-300
250_259	0	0	0	0	0	0	0	0
500_250	197.57	222.48	240.51	228.52	213.47	103.09	94.66	79.65
250_201	1	1	1	1	1	1	1	1
250_260	79.69	78.33	77.96	75.3	72.34	81.89	80.94	79.29
260_270	59.24	57.85	57.48	59.87	56.97	66.53	70.67	74.03
260_261	20	20	20	15	15	15	10	5
201_202	1	1	1	1	1	1	1	1
30_31	-215.97	-225.43	-222.59	-219.03	-217.93	-190.41	-157.44	-139.29
30_32	-215.98	-225.43	-222.58	-219.03	-217.93	-190.41	-157.44	-139.29
30_20	196.23	196.28	185.7	185.69	196.24	196.15	148.13	127.23
30_21	18.07	25.14	25.14	25.14	25.14	18.07	18.06	18.06
30_210	152.57	162.58	167.07	162.54	157.14	120	116.95	110.3
30_270	61.29	62.68	63.05	60.67	53.47	43.9	29.68	21.28
200_220	-80.75	-84.68	-81.99	-79.15	-82.48	-80.16	-83.54	-86.65
21_22	18	25	25	25	25	18	18	18
520_521	737.58	767.1	784.22	773.53	752.9	706.33	672.08	670.53
10_210	94.74	95.73	98.25	96.13	94.44	79.52	86.11	88.1
500_520	900.42	1059.02	1100.16	1070.44	1056.76	784.08	763.77	690.2
10_241	-115.37	-123.81	-126.45	-124.21	-122.34	-106.53	-111.19	-110.1
200_521	-66.58	-62.1	-68.22	-66.53	-59.9	-33.33	-31.08	-32.53
220_240	-195.15	-209.84	-217.57	-214.56	-207.44	-173.45	-166.51	-159.35
220_221	110	120	130	130	120	90	80	70
200_210	-51.74	-57.7	-59.69	-59.06	-57.01	-49.21	-37.68	-33.01
20_40	190	190	180	180	190	190	145	125
200_130	195	200	205	200	195	160	150	150
210_140	195	200	205	199	194	150	165	165
270_150	120	120	120	120	110	110	100	95
10_12	18	25	25	25	25	25	23	20

The calculation results for an individual hour under the RASTR program operated in the Dispatching Center of the Kazakh Power Grid confirmed the correctness of the electric mode calculation. In that case we assigned a load and generation in all nodes except the 251 node. We obtained voltages and transfers with a sufficient extent of coincidence. We could make only a subjective estimation of the correctness of load distribution within a day.

USER'S GUIDE

Specialists of the EPIC Program developed an interface that enables automating the GAMS model building. For those who will create their own interface, below we give the GAMS model text with comments. These comments say what information is entered and in what part of the program.

Listing time steps. If you do calculations for one time step only, you should leave only t1.

```
SETS ttt time / t1,t2,t3,t4,t5,t6,t7,t8,t9,t10, t11,t12,t13,t14,t15,t16,t17,t18,t19,t20, t21,t22,t23,t24,
rrr/;
SETS t(ttt) time / t1,t2,t3,t4,t5,t6,t7,t8,t9,t10,
t11,t12,t13,t14,t15,t16,t17,t18,t19,t20,t21,t22,t23,t24/;
```

Listing all nodes

```
SETS
MT /
10,12,250,251,252,253,258,259,20,21,22,260,261,270,50,
30,31,32,40,201,202,221,130,140,200,210,220,240,241,
243,500,520,521,total /
m(MT) /
10,12,250,251,252,253,258,259,20,21,22,260,261,
270,150,30,31,32,40,201,202,221,130,140,200,210,220,240,241,243,500 520,521 /
```

Listing all arcs

```
sets
Duga connection
/250_241, 250_240, 241_243, 500_251, 500_252, 500_253, 250_258, 250_259, 500_250,
250_201, 250_260, 260_270, 260_261, 201_202, 30_31, 30_32, 30_20, 30_21, 30_210, 30_270,
200_220, 21_22, 520_521, 10_210, 500_520, 10_241, 200_521,
220_240, 220_221, 200_210, 20_40, 200_130, 210_140, 270_150, 10_12 /;
```

Listing transformer arcs

```
set trans(duga) /
241_243,500_251,500_252,500_253,250_258,250_259,
500_250,260_261,201_202,30_31,30_32,21_22,520_521
220_221,200_130,210_140,270_150,10_12 /;
alias(m,M1);
alias(m,m2);
```

Listing the nodes with generation

```
sets
me(m) electro supplies /251,252,253,258,259,31,32,520/
```

Listing balancing nodes

```
balans(m) /520,251/;
```


The connection that defines the beginning of an arc

SETS

u_duga(m,duga)/ 250.250_241, 250.250_240, 241.241_243, 500.500_251, 500.500_252,
 500.500_253, 250.250_258, 250.250_259, 500.500_250, 250.250_201, 250.250_260,
 260.260_270, 260.260_261, 201.201_202, 30.30_31, 30.30_32, 30.30_20, 30.30_21, 30.30_210,
 30.30_270, 200.200_220, 21.21_22, 520.520_521, 10.10_210, 500.500_520, 10.10_241,
 200.200_521, 220.220_240, 220.220_221, 200.200_210, 20.20_40, 200.200_130, 210.210_140,
 270.270_150, 10.10_12/;

The connection that defines the end of an arc

SETS Duga_u(duga,m)/

250_241.241,250_240.240,241_243.243,500_251.251,500_252.252,
 500_253.253,250_258.258,250_259.259,500_250.250,250_201.201,
 250_260.260,260_270.270,260_261.261,201_202.202,30_31.31,
 30_32.32,30_20.20,30_21.21,30_210.210,30_270.270,200_220.220
 21_22.22,520_521.521,10_210.210,500_520.520,10_241.241,
 200_521.521, 220_240.240, 220_221.221, 200_210.210,
 20_40.40, 200_130.130, 210_140.140, 270_150.150
 10_12.12 /;

ATTENTION!!! A transformer arc always begins with a node with the highest voltage. No constraints exist for simple arcs.

```
sets u_duga_u(m,duga);
u_duga_u(m,duga)$(Duga_u(duga,m))=yes; u_duga_u(m,duga)$(u_duga(m,duga))=yes;
*****
```

Entering an active consumption schedule

table req(m,t)

	t1	t2	t3	t4	t5	t6	t7	t8
12	20	20	20	20	25	25	25	20
22	15	15	15	15	25	25	35	25
261	5	5	5	5	10	10	15	15
150	90	90	90	90	95	95	95	95
40	100	100	100	100	100	175	175	140
202	1	1	1	1	1	1	1	1
221	50	55	60	70	120	110	115	100
130	100	105	105	180	195	195	195	180
140	165	167	168	192	202	197	191	183
243	15	15	15	15	20	20	20	20
520	130	130	130	192	195	293	380	165
521	611	614	624	642	677	664	669	676
250	0	0	0	0	88	81	78	50
+	t9	t10	t11	t12	t13	t14	t15	t16
12	20	18	18	18	18	18	18	18
22	15	11	11	11	11	11	11	15

261	15	10	10	10	10	10	10	10
150	95	80	80	90	75	80	100	125
40	80	80	95	95	95	95	95	95
202	1	1	1	1	1	1	1	1
221	80	70	70	60	65	65	70	85
130	160	150	150	160	160	170	170	185
140	170	165	175	190	190	200	195	195
243	20	15	15	15	15	15	15	15
520	155	150	145	145	145	140	140	140
521	660	629	624	618	624	621	618	624
250	23	24	32	32	30	38	32	50
+	t17	t18	t19	t20	t21	t22	t23	t24
12	18	25	25	25	25	25	23	20
22	18	25	25	25	25	18	18	18
261	20	20	20	15	15	15	10	5
150	120	120	120	120	110	110	100	95
40	190	190	180	180	190	190	145	125
202	1	1	1	1	1	1	1	1
221	110	120	130	130	120	90	80	70
130	195	200	205	200	195	160	150	150
140	195	200	205	199	194	150	165	165
243	20	25	25	25	25	25	20	15
520	162	291	315	296	303	160	160	150
521	671	705	716	707	693	673	641	638
250	85	83	91	87	84	14	14	14

Entering a reactive consumption schedule
table req_k(m,t)

	t1	t2	t3	t4	t5	t6	t7	t8
12	9	9	9	9	12	12	12	9
22	7.26	7.26	7.26	7.26	12	12	17	12
261	2	2	2	2	5	5	7	7
150	43	43	43	43	46	46	46	46
40	25	25	25	25	25	50	50	40
202	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
221	24	26	29	34	58	53	55	48
130	48	165	51	87	94	94	94	87
140	80	81	81	93	98	95	92	88
243	7	7	7	7	9	9	9	9
520	42	42	42	42	28	28	21	21
521	278	279	275	291	308	302	295	298
250	0	0	0	0	29	29	20	0
+	t9	t10	t11	t12	t13	t14	t15	t16
12	9	8	8	8	8	8	8	8

22	7	5	5	5	5	5	5	7
261	7	5	5	5	5	5	5	5
150	46	39	39	43	36	39	48	60
40	75	75	50	50	50	50	50	50
202	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
221	38	34	34	29	31	31	34	41
130	77	72	72	77	77	82	82	89
140	82	80	85	92	92	97	94	94
243	9	7	7	7	7	7	7	7
520	21	28	28	28	28	28	35	28
521	300	292	296	298	291	295	299	320
250	0	0	0	0	0	0	0	0
+	t17	t18	t19	t20	t21	t22	t23	t24
12	8	12	12	13	12	12	11	9
22	8	12	12	12	12	8	8	8
261	9	9	9	7	7	7	5	2
150	58	58	58	58	53	53	48	46
40	75	75	75	75	75	75	45	35
202	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
221	53	58	63	63	58	43	38	34
130	94	97	99	97	94	77	72	72
140	94	97	97	96	94	72	80	80
243	9	12	12	12	12	12	9	7
520	14	0	0	7	7	21	28	35
521	317	326	319	314	305	305	294	293
250	27	30	30	29	24	0	0	0

Assigning resistance of arcs

PARAMETERS r(duga) /

250_241	0.28
250_240	0.28
241_243	6.65
500_251	0.72
500_252	0.72
500_253	0.72
250_258	0.16
250_259	0.32
500_250	0.48
250_201	2.4
250_260	2.44
260_270	1.76
260_261	11.44
201_202	5.72
30_31	0.38
30_32	0.38

30_20	0.85	
30_21	1.03	
30_210	3.77	
30_270	3	
200_220	2.6	
21_22	7.94	
520_521	0.255	
10_210		3.41
500_520		1.37
10_241		4.92
200_521		5.1
220_240		5.2
220_221		0.5
200_210		6.24
20_40		6.3
200_130		0.51
210_140		0.5
270_150		1.265
10_12		9.4

/;

Assigning reactance of arcs

PARAMETERS	x(duga) /	
250_241	1.2	
250_240	1.2	
241_243	169	
500_251	43.9	
500_252	43.8	
500_253	43.5	
250_258	8.35	
250_259	16.7	
500_250	28.8	
250_201	9.3	
250_260	10.7	
260_270	7.72	
260_261	276	
201_202	138	
30_31	14.6	
30_32	14.6	
30_20	3.67	
30_21	4.43	
30_210	21	
30_270	16.8	
200_220	10.1	
21_22	165	
520_521	14.75	

```

10_210      13.5
500_520     16.82
10_241      19
200_521     20
220_240     20.3
220_221     22.82
200_210     24.5
20_40       24.6
200_130     25.24
210_140     26.66
270_150     50.65
10_12       269

```

/;

Entering capacitive susceptance of arcs

PARAMETERS b_d(duga) /

```

250_241     -8.2,
250_240     -8.2,
250_201     -60,
250_260     -65.7,
260_270-47.5
30_20       -23.6
30_21      -28.5
30_210    -141
30_270    -108
200_220    -64.8
21_22      0
520_521    0
10_210   -86.5
500_520   -849
10_241   -122
200_521   -129
220_240   -130
220_221    0
200_210   -158
20_40    -159
200_130    0
210_140    0
270_150    0
10_12     0 /;

```

Entering a transformation for transformer arcs. You should remember that we define the coefficient as the ratio of the lowest voltage to the highest.

PARAMETERS kt(duga) /

```

241_243     0.167,      500_251     0.03,
500_252     0.03,      500_253     0.03,
250_258     0.065,     250_259     0.065,
500_250     0.469,     260_261     0.167,

```

```

201_202      0.167,      30_31      0.065,
30_32        0.065,      21_22      0.175,
520_521      0.486,      220_221    0.55,
200_130      0.55,        210_140    0.55,
270_150      0.55,        10_12      0.043
/;

```

Entering conductance of arcs

```
PARAMETERS g_d(duga);
```

```
g_d(duga)=0;
```

Entering conductance of a shunt in a node

```
PARAMETERS g_u(m);
```

```
g_u(m)=0;
```

Entering susceptance of a shunt in a node

```
PARAMETERS b_u(m);
```

```
b_u(m)=0;
```

Entering nominal voltage of nodes

```
PARAMETERS UNOM(m) /
```

```

10  220, 12  10.5, 250  220, 251 15.75,
252 15.75, 253 15.75, 258 15.75, 259 15.75,
20  220, 21  220, 22 35, 260 220,
261 35, 270 220, 150 110, 30 220,
31  15.75, 32 15.75, 40 220, 201 220,
202 35, 221 110, 130 110, 140 110,
200 220, 210 220, 220 220, 240 220,
241 220, 243 35, 500 500, 520 500,
521 220 /;

```

Generation unit cost for generating sources

```
PARAMETERS price(m) /
```

```

251 1
252 1
253 1
258 1
259 1
31  1
32  1
520 10
/;

```

Entering a tariff on consumption

```
SCALAR Tarif /2/;
```

Entering tangent of the angle between active and reactive power of generators

```
PARAMETERS tgFi(m) /
```

```
251 0.391
```

```

252      0.15
253      0.15
258      0
259      0
31      0.4
32      0.4 /;
      Entering minimum capacity of generators
PARAMETERS PMIN(m) /
251      0
252      0
253      0
258      300
259      0
31      0
32      0
520     0
      /;

```

```

      Entering maximum capacity of generators
PARAMETERS PMAX(m) /
251      667
252      667
253      667
258      667
259      333
31      300
32      300
520     2000
      /;

```

Further goes the block of equation, which we would not advise to change.

Then you should assign constraints on variables.

```

u_d.l(m,t)=UNOM(m);
u_mod.l(m,t)=UNOM(m);
u_mod.lo(m,t)=5;

u_mod.lo('520',t)=495;
u_mod.up('520',t)=525;

e_d.lo(m,t)=PMIN(m);
e_d.up(m,t)=PMAX(m);

```

Then, the operators MODEL and SOLVER start

```
MODEL VAN /ALL/;
```

```
SOLVE VAN USING DNLP maximaZING obj;
```

If you conduct your calculation for a day you should include the output file 'vivod24'

```
$INCLUDE 'vivod24';
```

If you conduct your calculation for one hour you should include the output file 'vivod1'

\$INCLUDE 'vivod1';

To this report we attach a soft copy of the model with reference data for the Dushanbe – Vakhsh power system and comments in Russian.

CONCLUSION

The model of optimizing the electric power mode is ready for application in power systems to solve problems of both day-to-day operation and long-term planning.

The model enables us to solve the problem of optimal load distribution among stations during a day and to calculate the electric mode for every hour at the same time.

The model enables us to conduct optimization under different criteria (maximized profits, minimized generation costs, minimized losses in networks)

The model is applicable to calculate the electric mode without any optimization.

However, it is necessary to conduct further studies to take into account additional factors (entering statistical characteristics of transformers and loads, U-features of generating sources, etc).

Specialists of the EPIC Program/USAID developed an interface to automate entering a loading diagram and building a GAMS model. This may considerably simplify modeling, and therefore the industrial engineer would not need profound knowledge of programming.

Description of the Modeling System for Energy Management Problems

1. Introduction

The complex of programs is designed by the EPIC staff in cooperation with specialists of Barki Tochik and KEGOC. The complex of programs is intended for automated creating of a file of the GAMS model (file with the **.gms** extension) that can be compiled by the GAMS system. The GAMS model is created by specialists of Barki Tochik and KEGOC.

EPIC specialists in cooperation with the participants of the technical group from the Republic of Kazakhstan and Republic of Tajikistan have created this complex of programs proceeding from the complex of programs of BVO Syr Darya as a basis.

2. Description of an Example Energy Management Problem

As a test electric power network the actual electric power network of Tajikistan is selected. The final report presents the electrical power network, reference data and text of the model designed by the Barki Tochik and KEGOC specialists. Initially the model was created by editing the reference text according to the GAMS technology (being a sufficiently difficult operation accessible only to specialists of the highest skill). However below is the description of a complex of programs much easier for users when writing the model thereby transforming the model to the class of models for broad usage.

3. Structure of the Program System to Create Optimization Models for Electric Systems

The complex of programs assisting a user in creating a design optimization model includes a group of interacting executable modules:

- | | |
|-----------------|--|
| 1. MENU_R_E.EXE | - main control // program - interface |
| 2. R_WRK_W.EXE | - module of defining a path to a working directory |
| 3. R_KLV_EN.EXE | - module of creating electric power networks |
| 4. R_REGIME.EXE | - module of electric power networks correction and arch features assigning |
| 5. R_1_EN.EXE | - module of formation of a list of electric power network nodes |
| 6. R_22E.EXE | - data entry editor |
| 7. BUILD_E.EXE | - GAMS code generator |
| EGAVGA.BGI | - PASCAL graphics driver |
| 8. TRANSL.EXE | - simplified file translator (taken from BVO Syr Darya |
| DICTION | - dictionary to the simplified file translator |
| 9. PE.EXE | - text editor |
| PE2.PRO | - extension capacities of text editor |
| PE2.HLP | - explanations to the editor operation |

Before operation make sure that all the aforementioned files are located together in some directory. In addition it is recommended, before starting the program complex operation, to create at least one internal subdirectory.

4. Interface

The main control program of the complex is the program

“INTERFACE” menu_r_e.exe

The working window at the interface start is shown in Figure 1. It has to appear in starting the menu_re.exe in DOS system with file EGA VGA.BGI available.

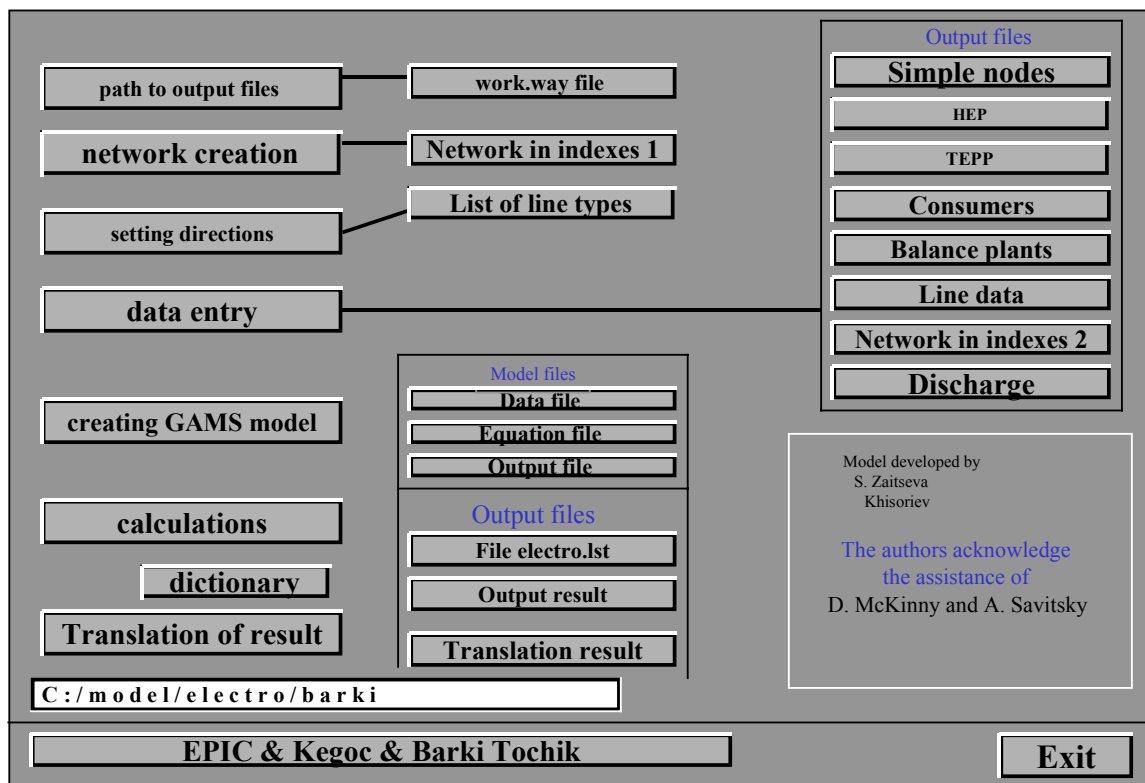


Figure 1. Main control panel window.

The interface is made on the principle as follows: on the left there are buttons of executing modules. They are located in the sequence these modules are run to create a GAMS model, carry out calculation and obtain results of calculation in the language included as the second language in the internal dictionary of the complex.

This means if you start in succession all executing modules, you will have the calculation result both in English (the language of the GAMS technology) and in any other language as option.

To activate any module, move the mouse pointer to a button and press the left mouse button. Detailed description of every module operation is given below in separate paragraphs.

The button of each executing module (*.exe) is connected with a line to a block with buttons to view output files obtained as a result of executing the module. To view and edit the mentioned files the internal editor **PE.EXE** is used supplied together with its operating instructions **PE2.HLP**. The operating instructions in this internal editor are activated with the functional button **F1**. To exit this editor, press key **F4**.

On the lower part of the interface in a special window a path to working files is recorded for this complex of programs operation. This is a comment enabling the user to know exactly in which directory are the reference data, the model and the calculation results. At the moment of the first start of the "**menu_r_e.exe**" the window shows a path to the directory where the **interface** module is located.

By default this is just the working directory. The record in this dialog box will change after executing the module of selection of path to working files. This module operation is described in the paragraph below.

In the lowest part of the interface there is the **EPIC & KEGOC&BARKI TOCHIK** button. If you point to this button and press the left mouse button, you will see a box with a list of implementers of this program. To return to the interface, press the **F4** key on the keyboard.

5. Path to Output Files Module

After installation of a program package to make electric networks, it is necessary to start this module at least once. This module automatically creates files with the records of this software location and the path to the working directory, which will comprise initial data and results of calculations. The button to start this module is located in the upper left corner of the main working of the control module **MENU_R_E.EXE**. In the lower left corner of the working panel there is a black box showing the location of source and resulting data files. The location is defined with a DOS system of symbols.

This module is started by pressing the mouse left button when the mouse pointer is on the button **PATH TO OUTPUT FILES**.

In doing so the complex control program transfers control to the individual executable **R_WRK_W.EXE** module. The image consisting of two text columns should appear on the screen. In the first column every line includes 8 symbols and defines the name of one subdirectory located inside the directory that contains the program complex. In case when a number of subdirectories exceeds the number of lines on the screen, the complex starts scrolling in the **CRT** mode using pointer control keys. The very last line in this column has a fixed name, **NEW**. Only when the pointer is in this line, the user has access to Latin letters **KEYBOARD**. When the word **NEW** is changed into any other word, a new subdirectory named with this new word appears in a working subdirectory. If the user is on some line and presses **ENTER**, then the

directory named thereby becomes the subdirectory of current optimization calculations. Not to forget the essence of an optimization task located in some subdirectory, the user may insert an explaining comment in the right column. The complex saves a comment of each directory on the hard disc in the **model.cfg** text file and records the name of a current working directory in the **work.way** text file. The user can gain access to each of these files **work.way** and **model.cfg** using any text editor. The user can access the first file through a special button in the main menu. Access is useful if the user wants to place the calculation directory outside the directory that contains executable files. In this case the user should record the new path using the mode of editing the **work.way** file.

The **work.way** file is updated constantly and includes comments that elucidate the meaning of the first line of this file. A special algorithm checks the **model.cfg** file to be consistent with the actual structure of the directory. If a striking discrepancy is found, the file is updated automatically. This special algorithm aims to keep as many previous comments to existing and recognized directories as possible.

In the **R_WRK_W.EXE** module you can perform the following operations:

- To create a new subdirectory in which output files of all executable modules will be recorded, in the current directory.
- To insert a comment into the subdirectory or modify the text of an already existing comment.
- To choose an already existing subdirectory in the current directory. In this subdirectory (name it "a working directory") all output files of executable modules will be recorded.

Creating Subdirectories

If you want to create a subdirectory, then you should move down to the line with the **NEW** subdirectory name using arrows on the keyboard (↑↓) and instead of **NEW** introduce a new name of the subdirectory (name's length should not exceed seven characters). After the introduction of a new name, press the **Enter** key on the keyboard.

If you press **Enter** while **NEW** is highlighted (i.e. you have not changed the name of the **NEW** file), then in the line for comments you will see a message: "**You did not assign a name for a new subdirectory**".

Inserting comments

You can insert a comment for any subdirectory in the comment line (for instance, a more complete name of an electric network). By default, the text of the comment looks as follows - ("??...??"). The comment length should not exceed 40 characters. The comment text is inserted through the keyboard. To insert a comment:

- Select the subdirectory you need using arrows on the keyboard (↑↓).
- Then, using the keyboard arrows (↑↓), point to the comment.
- Insert the text of you comment.

- After you completed the insertion of the comment text, press **Enter** on the keyboard or leave the comment line using arrows ↑ or ↓.

If you want to change the comment text (for example correct spelling mistakes), then you should completely reinsert the entire comment text. Using any editor, you can also open the **model.cfg** file and make necessary changes in the file itself.

Selecting Working Subdirectory

Select your working subdirectory as follows. Specify your working subdirectory using keyboard arrows (the color of the name of this working subdirectory will change from yellow to white) and press the **Enter** key on the keyboard. With that you, having defined the path to your working directory, exit the **PATH TO OUTPUT FILES** module.

The path to the working subdirectory will be recorded in a separate file (**work.way**), which you can view if you press the **File work.way** button in the main control panel. You can change the path directly in this file or assign an external directory or even a directory on another hard disk as your working directory.

6. Structure of the Work.Way File

Consider the structure of the work.way file using an example.

Assume that you are in the **OPTIMUM** directory and you want to record output files in the **Scheme_1** subdirectory, and this subdirectory has the following comment text: **Energy System of Tajikistan**. Then the **work.way** file (it always contains three lines) will have the look shown in the table below.

No. of file line	Contents of File Line	Note
Line 1	C:\OPTIMUM\SCHEME1\	Path to working subdirectory
Line 2	You will work in this subdirectory	Comment
Line 3	Energy System of Tajikistan	Comment to the Subdirectory Selected PATH TO OUTPUT FILES modules.

Only the first line of the **work.way** file is important for the complex of programs.

7. Creating Network Module

The **CREATING NETWORK (R_KLV_EN.EXE)** module serves to create a calculation scheme of the energy network. The maximum number of nodes in the calculation scheme allowable by the complex of programs is 500. An attempt to exceed this number leads to the activation of the memory protection algorithm. This algorithm overwrites the 500 line with the 501 line, automatically deleting the 500 line.

The **CREATING NETWORK** module can work only if there is a corresponding version of a graphics driver in PASCAL - egevga.bgi

When the **CREATING NETWORK** module is being executed, a new calculation scheme is created or the existing calculation scheme of the energy network is modified. Each node of the calculation scheme is assigned with:

- **External name** (usually it is presented by names of hydroelectric plants (HEP), thermal electric power plants TEPP), consumers, etc.).
- **National Identity** (since the application program package is created by specialists of Central Asia, it stipulates possible consideration for identity of that or another node of the energy network to one of the Central Asian countries). These data are essential for tasks of the complex interstate management and will be used in further activities.

The results of executing **CREATING NETWORK** module are recorded in the **el_net.out** file. The user can locate the path to this file using data in the **work.way** file.

The **CREATING NETWORK** module is started as follows: Point to the **CREATING NETWORK** button of the main control panel (Figure 1) and press the left button of the mouse. An image appears on the screen (Figure 2). This image includes a working area (big black square with a calculation scheme - for convenience the color in the figure is inverted). Above and on the left there are buttons and dialog boxes.

Figure 2 shows the calculation scheme for our test problem made in the **CREATING NETWORK** module and representing the actual energy system processed by specialists from Kazakhstan and Tajikistan. The calculation scheme of the energy network is built on the working area.

In the general case, the calculation scheme of the model is a system of calculated arcs (further on we will say simply "arcs") connected in accordance with relations that exist between these arcs under actual circumstances. Each arc includes two nodes (the first and the second) and a straight line connecting these two nodes. Under actual circumstances, the node is an object, and the straight line connecting two nodes means that there is a certain relationship between these two objects. If some node (object) has connections with several other nodes (objects), then this node belongs to several arcs. On a calculation scheme, several lines connecting this node with corresponding nodes will go off it.

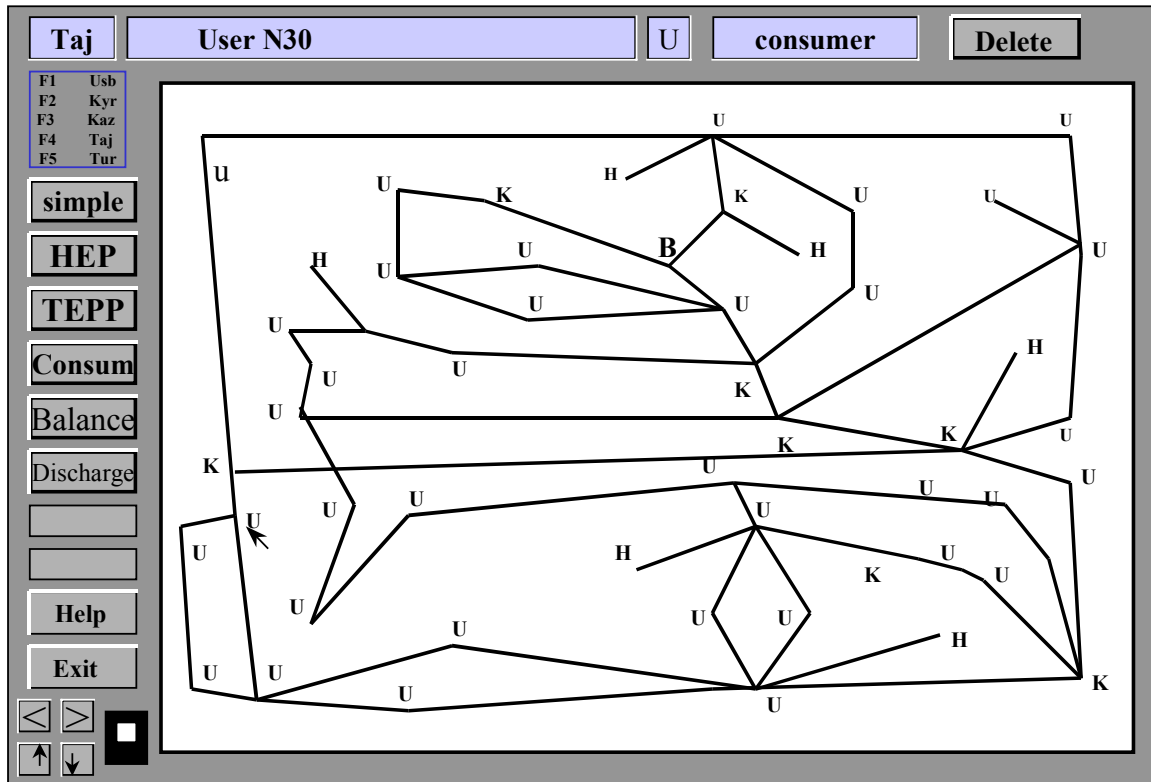


Figure 2. Screen view in the mode of creating energy network.

In the **CREATING NETWORK** module, you perform the following operations:

1. Creating a system of nodes and arcs of the calculation scheme.
2. Changing the internal name (type) and national identity of the node.
3. Changing the external name of the node.
4. Deleting the node and its arc from the calculation scheme
5. Getting help.
6. Exiting the module.

Consider each operation performed in the **CREATING NETWORK** module in details.

Creating a System of Arcs of the Calculation Scheme

To create the first node of an arc, move the mouse pointer to the place of the working area you need (it may be any point on the working area or any already existing node) and press the left button of the mouse. A sound signal is a message to the user that the first node of the arc being created has been already made and is present in the scheme. No signal informs the user that the node being created has not been linked with already existing calculation scheme. After that (to create the second node of an arc), having released the left mouse button, point to another point of the working area (it may be also any point on the black area or any already existing node). At

this time, a red line should appear on the screen. One end of this line is at the point of node 1 of the arc; the second end is at the position of the mouse pointer. Press the right mouse button. A new arc should appear on the screen: two nodes and a line connecting these two nodes, all of white color. Letter "K" of the green color will appear near each newly created node. It is caused by the fact that by default each node is assigned with the "simple node" type, with the internal name (index) "K" and external name "?????????????" which may be later changed to necessary ones (see below).

In making a scheme, there is a rule embedded in the program by a special algorithm: if in an arc being newly created you set the second node very close to the first one (closer than 0.5 cm on the screen), then both the first and the second nodes will be treated by the program as one node. Such an arc will not be included in the scheme. On the screen, if you call the module again, you will not see this supershort arc.

We advise not to set a new node on the lines that form arcs (on white arcs), because a difference between computer and visual sensing of the calculation scheme may occur. It is easier to check the existence of such imaginary links in the ASSIGNING DIRECTIONS module by slight deformation of the created network.

By default a node is assigned with:

- Node type - simple, and a corresponding internal name (index) for a simple node - (K)
- External name (?????????????)
- National identity - numerical index 1.
-

To view the features of nodes, there are dialog boxes located above the working area (Figure 2).

The contents of these from left to right will be described as follows.

1. The dialog box displays the national identity of the node.
2. The dialog box displays the external name of the node.
3. The dialog box displays the index that specifies the type of the node.
4. The dialog box displays the type of the node.

To change features of a node by default, use buttons on the left from the working area. To select a button to define a node type, you use the mouse (the right-hand button) or control keys of the **KEYBOARD**.

Changing Internal Name (Node Type)

You change the internal type of the node using the buttons for assigning node types. These buttons are located on the left side of the working area (Figure 2). The inscription on an active button that defines the node type is black while other buttons have inscriptions of the grey color.

There are the buttons "**Simple**", "**HEP**", "**TEPP**", "**Consumer**", "**Balance**" and "**Discharge**".

To change the internal name (type) of the node you should:

- Point to the node you need (the color of the node should change and become red).
- Not moving the mouse pointer from the node (the color of the node constantly remains red), you select the node type you need (the inscription of the button with the name of a necessary node type should become black, that is you activate the button of selecting a node type) by pressing arrows on the keyboard (↑ or ↓). You can activate the button of selecting a node type using the mouse (the right-hand button)
- Press the **Tab** key on the keyboard.

The letter that defines the node (index) will change in accordance with Table 1 given below. Corresponding changes will also take place in dialog boxes.

Below is given the table of types of nodes and corresponding symbols in internal names (or Indexes). Full internal names (letter index + ordinal number of the node of a specific type in the calculation scheme) will be assigned to nodes in the **DATA ENTRY** module.

Types of nodes	Internal name (or Index)
Simple	K
HEP	G
TEPP	H
Consumer	U
Balance	B
Discharge	O

Changing National Identity of the Node

You change the national identity of a node using functional keys **F1, F2, F3, F4** or **F5** on the keyboard. On the left side of the working area there is an inquiry window (Figure 2) enabling you to select a functional key correctly.

Below is given a table showing national identity of a node, the corresponding functional key on the keyboard, and the index set in this package of programs. At the user's desire the sequence of Indexes can be changed, since the specific name of a country is for referential use and is not employed in the calculation model.

To change the national identity of a node you should:

- Point a node (color of this node should change for red).
- Not moving the mouse pointer from the node (color of the node should be constantly red), press one of functional keys on the keyboard (**F1, F2, F3, F4** or **F5**). You will see corresponding changes in dialog box 1.

Attention! Since by default the complex assigns each node with the **K-simple** type, we advise you to carefully review inscriptions of nodes checking if one node belongs to two different types. You can see this discrepancy in the form of simultaneous displaying of the same symbols in one place. Types of such controversial nodes should be reassigned. Otherwise this duality can arise computational problems.

Changing External Name of a Node

To change the external name of a node you should:

- Point to a node (color of this node should change for red), and a prior assigned external name of the node should appear in the dialog box (external name of the node) instead of line “+++++”. If that external name was not assigned, then by default it will be the “?????????????” line.
- Enter a new external name of the node from the keyboard. At the moment the external name is being defined, the mouse is deactivated, and the dialog box becomes blue.
- As you entered a new external name of the node, press the **Enter** functional key on the keyboard. The complex automatically cancels the entry mode, as symbols used to assign the external name are over. The dialog box (external name of a node) should change its color from blue to black when the entry of the external name is cancelled. The mouse is activated again.

The maximum allowable length of the external name is 44 characters.

Deleting Arcs from the Calculation Scheme

To delete nodes and respective arcs from the calculation scheme, there is the **DELETE** button located in the upper right corner of the screen (Figure 2).

To delete arcs from the calculation scheme, you should:

- Point to a node (color of this node should change for red) and press the left mouse button.
- Having released the left mouse button, point to the **DELETE** button and press the right mouse button.

When you apply the **DELETE** mode, you also delete all nodes forming arcs with the given node provided they (these nodes) do not belong to other arcs.

Scrolling of the module working window

On the left lower side of the screen there are buttons of the working window scrolling control. On the right you can see the total working area intended in the computer memory for creating the energy system. In this area there is a small square indicating actually the current location of the

working window, i.e. the area accessible at that moment for the energy system formation. Due to scrolling, you can create extremely bulky and huge energy systems without special saving of the working area of the module of energy system formation.

Getting Help

To get help, there is special button **HELP** in the left lower corner of the working window (Figure 2).

To enter the **HELP** mode, you should:

- Point to the **HELP** button
- Press the right mouse button. Information about all features of this module will appear on the screen.

To exit the **HELP** mode, you should press any key on the keyboard.

Quitting the module

To quit the **CREATING NETWORK** module, there is the **EXIT** special button in the left lower corner of the working window (Figure 2).

To quit the **CREATING NETWORK** module, you should:

- Point to the **EXIT** button
- Press the right mouse button.

An image of three buttons appears on the screen enabling the user to perform: 1) exit; 2) exit without saving the changes in the energy network; 3) exit with saving the changes.

If you chose the **SAVE and EXIT** button, then after pressing the left mouse button you will see a message box with comments on the number and type of nodes included in the calculation scheme. These comments can be very useful. Apart from this, you will see a table specifying subsequent operations.

**You decided to save a new calculation scheme.
If you added or deleted some nodes,
then you should create all output files using
DATA ENTRY module again.
If you want to save a newly crated network, press Y.
If you do not want to save a newly created network, press any key.**

In the process of the **saving** mode all files with data on the calculation scheme that form as consecutive modules are executed will be renamed in the working subdirectory. The names of these files will remain, but all these files will have the ***.bak** extension. Only the newly formed **Network in Indexes 1** file will exist in the working subdirectory. In that situation files named **copy_1.new**, **copy_1.bak**, **copy_2.bak** and **copy_2.new** will be automatically created where all changes in the data will be recorded with necessary comments. The special block for checking the correctness of the scheme building will check a newly created scheme and will delete impossible combinations of arcs and nodes from it. Therefore, after you created the scheme, we advise to reenter the **CREATING NETWORK** module and assess visually the availability of changes in the calculation scheme that were made by the program.

If the user wants to quit the **CREATING NETWORK** module at once, then he should press twice the **Esc** functional key on the keyboard. The user will quit the **CREATING NETWORK** module without saving the changes made.

Execution of the **CREATING NETWORK** module results in the formation of the **Network in Indexes 1** file - **el_net.out**. This file is actually the basis of all further operations of the complex, and therefore we should devote some time to the description of its structure.

Structure of Output File of CREATING NETWORK Module - the Network in Indexes 1 - el_net.out

Consider the structure of an output file created by the **CREATING NETWORK** module for our test problem - the **Network in Indexes 1** file.

To open the **Network in Indexes 1** file, probably for editing, you should:

- Point to the **Network in Indexes 1** button
- Press the left mouse button.

An output file after executing the **CREATING NETWORK** module for our calculation scheme looks as follows:

The first ten lines of the output file are always occupied by a reference table, where digital codes of node types (first column of the table) and national identity of the node (second column of the table) are specified. This table looks as is shown below.

The following five lines of the output file are names of areas of the main table, in which all data on the calculation scheme of the model are given.

The first table area (first column) is named **N**. In this area there is the ordinal number of the arc appearing on the scheme in the process of creating this scheme as module **CREATING NETWORK** is executed.

The following four areas (columns) are united under the general name of **CONNECTIONS**. Each area (column) has a subname (**x, y, x, y**). Each pair of figures (**x** and **y**) are the coordinates of nodes (in pixels) in the arc on the working area of the **CREATING NETWORK** module. The first pair of coordinates **x** and **y** is coordinates of the node in the arc under the condition that the line in the arc connecting this pair of nodes is directed from the first node to the second. Each area (column) is provided with 5 positions in the line. Node coordinates can be within the range of 0 to 4,000. There should be not less than one position of spaces

Next pair of areas (columns) is united under the general name of **TYPES**, and each area (column) has a subname (**1** and **2**). Here are given numerical codes of node types in accordance with the reference table provided at the beginning of the output file. In the area (column) subnamed **1**, there are numerical codes of a node type for the first node in the arc. In the area (column) subnamed **2**, there are numerical codes of a node type for the second node in the arc. As for coordinates of nodes, that node is considered the first in the arc from which a connection is directed to another node. For example, flow is directed from the first node to the second. Each numerical code of a node type (area) is provided with 2 positions in the line. There should be not less than one position of spaces between areas.

Next pair of areas (columns) is united under the general name of **STATES**, and each area (column) has a subname (**1** and **2**). Numerical codes of national identity of the node are given here in accordance with the reference table at the beginning of the output file. In the area (column) subnamed **1**, there are numerical codes of national identity for the first node in the arc. In the area (column) subnamed **2**, there are numerical codes of national identity for the second node in the arc. There should be not less than one position of spaces between areas.

Further there is a space and symbol => indicating the end of the description of the calculation scheme in numerical symbols.

Next there are external names of nodes (first the external name for the first node, then for the second). Each external name of the node is provided with 44 positions in the line. The external name of the first node is separated from the external name of the second node by the " | " symbol. If an external node name has a length of less than 44 characters, then it should be continued by the " _ " symbols up to the length of 44 characters. The complex adds these symbols automatically when you finish entering an external name in the **CREATING NETWORK** module. The external name of the second node should end with the ' <= ' symbol indicating the line end. Do not delete the " _ " symbol from the name because later it may cause problems to identify external names.

The view (a fragment) of the automatically created file **Network in Indexes 1 - el_net.out** is shown below.

Type: simple	1	State: Uzb	1
HEP	2	Kyr	2
TEPP	3	Kaz	3
Consumer	4	Taj.	4
Balance station	5	Tur.	5
Discharge	6		

Coordinates of the first and final nodes

N	x	y	x	y	Types	States	Name of the first node	Name of the second node
1	1276	1113	1232	1107	14	4 4	=> 540	541
2	1276	1113	1362	1170	15	4 4	=> 540	520
3	1232	1107	1218	1169	44	4 4	=> 541	542
4	1218	1169	1294	1166	44	4 4	=> 542	543
5	1218	1169	1282	1205	44	4 4	=> 542	544
6	1294	1166	1387	1200	44	4 4	=> 543	521
7	1282	1205	1387	1200	44	4 4	=> 544	521
8	1362	1170	1387	1200	54	4 4	=> 520	521
9	1387	1200	1399	1227	41	4 4	=> 521	200
10	1399	1227	1218	1209	14	4 4	=> 200	130
11	1218	1209	1169	1198	41	4 4	=> 130	120
12	1169	1198	1182	1144	13	4 4	=> 120	124
13	1169	1198	1126	1194	14	4 4	=> 120	110
14	1399	1227	1409	1267	11	4 4	=> 200	210
15	1142	1269	1409	1267	41	4 4	=> 140	210
16	1142	1269	1150	1228	44	4 4	=> 140	100
17	1142	1269	1150	1307	44	4 4	=> 140	90
18	1150	1228	1126	1194	44	4 4	=> 100	110
19	1150	1307	1137	1347	44	4 4	=> 90	80
20	1137	1347	1227	1314	44	4 4	=> 80	70
21	1227	1314	1373	1313	44	4 4	=> 70	46
22	1373	1313	1383	1342	44	4 4	=> 46	60
23	1383	1342	1308	1364	41	4 4	=> 60	66
24	1383	1342	1454	1363	43	4 4	=> 60	61
25	1308	1364	1307	1396	14	4 4	=> 66	42
26	1405	1109	1362	1170	15	4 4	=> 500	320
27	1405	1109	1433	1141	13	4 4	=> 500	251
28	1405	1109	1410	1060	14	4 4	=> 500	250
29	1410	1060	1340	1093	43	4 4	=> 250	258
30	1410	1060	1482	1102	44	4 4	=> 250	240
31	1482	1102	1469	1175	44	4 4	=> 240	220
32	1469	1175	1399	1227	41	4 4	=> 220	200
33	1410	1060	1590	1053	44	4 4	=> 250	241
34	1590	1053	1600	1124	44	4 4	=> 241	10
35	1600	1124	1409	1267	41	4 4	=> 10	210
36	1600	1124	1591	1243	44	4 4	=> 10	20
37	1591	1243	1481	1273	41	4 4	=> 20	30
38	1409	1267	1481	1273	11	4 4	=> 210	30
39	1410	1060	1249	1065	41	4 4	=> 250	280
40	1249	1065	1095	1054	11	4 4	=> 280	270
41	1095	1054	1146	1103	11	4 4	=> 270	30
42	1095	1054	1095	1199	14	4 4	=> 270	150
43	1095	1199	1101	1288	44	4 4	=> 150	162
44	1095	1199	1119	1136	44	4 4	=> 150	160
45	1101	1288	1101	1366	44	4 4	=> 162	161
46	1101	1366	1096	1437	44	4 4	=> 161	160
47	1096	1437	1193	1395	44	4 4	=> 160	58
48	1096	1437	1198	1437	44	4 4	=> 160	57
49	1193	1395	1385	1438	44	4 4	=> 58	50
50	1198	1437	1385	1438	44	4 4	=> 57	50
51	1481	1273	1543	1211	13	4 4	=> 30	31
52	1481	1273	1584	1289	14	4 4	=> 30	21
53	1584	1289	1576	1439	41	4 4	=> 21	52
54	1476	1318	1373	1313	44	4 4	=> 45	46
55	1476	1318	1576	1439	41	4 4	=> 45	52
56	1576	1439	1555	1355	14	4 4	=> 52	40
57	1555	1355	1527	1307	44	4 4	=> 40	42

58	1576	1439	1385	1438	14	44	=>	52	_____	50	_____	<=>
59	1385	1438	1483	1399	43	44	=>	50	_____	51	_____	<=>
60	1385	1438	1408	1393	44	44	=>	50	_____	56	_____	<=>
61	1385	1438	1359	1390	44	44	=>	50	_____	55	_____	<=>
62	1408	1393	1383	1342	44	44	=>	56	_____	60	_____	<=>
63	1359	1390	1383	1342	44	44	=>	55	_____	60	_____	<=>
64	1600	1124	1541	1089	44	44	=>	10	_____	12	_____	<=>

8. Setting Flow Direction Module

The **SETTING FLOW DIRECTION** module - **R_REGIME.EXE** serves to assign and change direction in arcs. The **SETTING FLOW DIRECTION** module can work only if there is a version of a graphics driver in PASCAL - **egavga.bgi**, in the same directory.

The file of data entry for the **SETTING FLOW DIRECTION** module is the **Network in Indexes 1** file. The adjusted **Network in Indexes 1** file is also an input file after the **SETTING FLOW DIRECTION** module has been operated. In addition, the **Lines.out** file is created indicating the type of the arc: a simple arc or a transformer arc.

The **SETTING FLOW DIRECTION** module is started as follows. Point to the **SETTING FLOW DIRECTION** button in the main menu. Press the left mouse button. The following image (Figure 3) appears on the screen. It includes the working area (a big black square, in the drawing the color is inverted), two buttons (**HELP** and **EXIT**) on the left of the area, and a dialog box above the area.

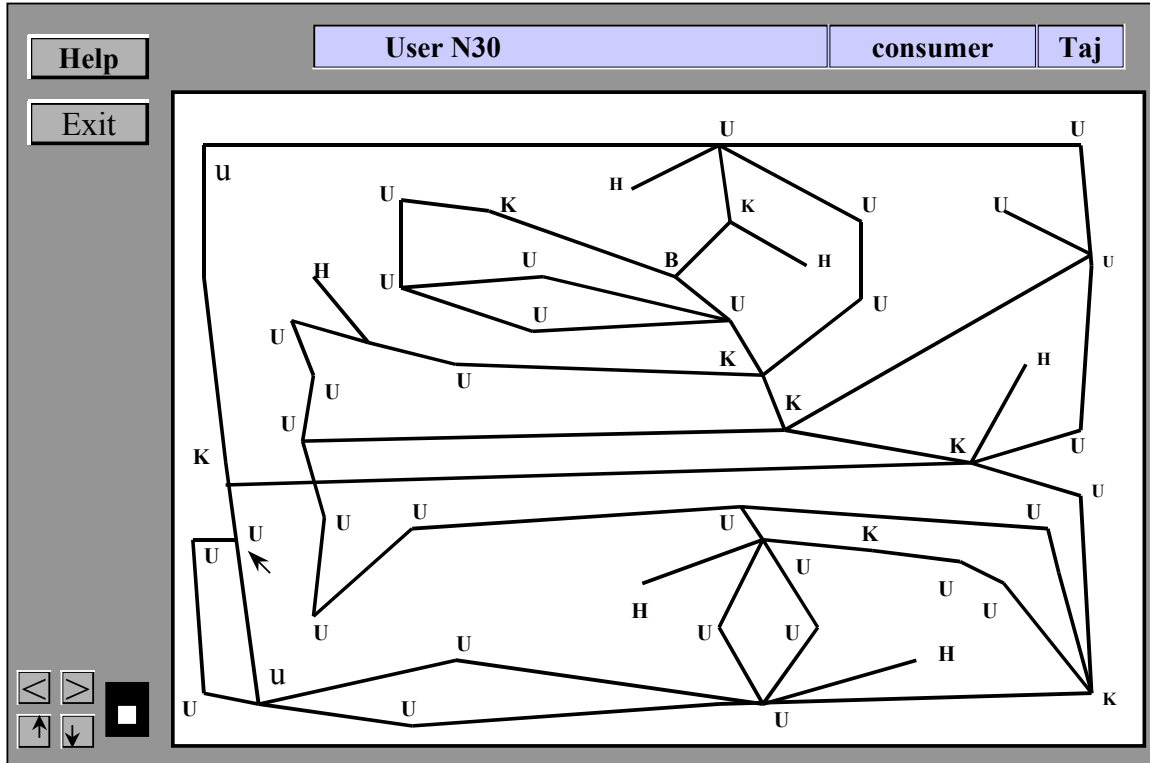


Figure 3. Screen view in the mode of assigning directions and types of the energy network arcs.

If you point to a node, then in the dialog box you will see the features of this node: external node name, node type and national identity of the node.

On the working area (Figure 2) you will see a calculation scheme of the model created as the **CREATING NETWORK** module is executed. Along the red lines connecting nodes in arcs, you will see moving yellow points. Direction of movement of these points indicates directions of connections among nodes. If white points move too fast, then point to any node, and the points will move slower.

The **SETTING FLOW DIRECTION** module enables performing two operations with the calculation scheme created as the **CREATING NETWORK** module is executed:

- Changing the configuration of a calculation scheme with modifying structural connections in it.
- Changing the direction of connections among nodes.
- Assigning arc types.
- Scrolling through a scheme that can be much bigger in size than the working area.

Changing Configuration of a Calculation Scheme

To change configuration of a calculation scheme you should:

1. Point to the node you need.
2. Press the left mouse button (at that you will hear a sound signal).
3. Pressing the left mouse button, drag the node to the position you need.
4. Release the mouse button at the moment when the node will be in the position you need.

At the moment of the scheme transformation some arcs will be colored green. These arcs are of the transformer type (see below).

Changing Flow Direction of Links among Nodes

The direction of markers determines the arc direction or the information specifying which node defines the beginning of the arc, and which one - the end. To change the flow direction of links among nodes, you should point to the middle of the straight line that connects nodes (at that you should hear a sound signal) and press the left mouse button. A prior existed direction of connection between nodes in the arc will change for the opposite.

Changing Types of Links among Nodes

Two types of arc can exist among nodes: **simple lines** and **transformer lines**. When this module is started for the first time, all moving markers are yellow labels (by default) corresponding to

simple lines. At that the user will receive information that the **lines.out** file is still unavailable and will be created in the process of this module execution.

The user can change the arc type. To change the type of the arc connecting two nodes, you should point to the middle of the straight line connecting the nodes (at that you will hear a sound signal) and press the right mouse button. The existing yellow color of the marker will change for red. Red markers move along transformer arcs. When you press the right mouse button again, the transformer arc will become simple. When exiting from the program, the **“lines.out”** file will be created comprising the data on the arcs and their types through the entire electric network. This file is actually a twin of the **“el_net.out”** file (described above). The difference is that instead of the pair of coordinates (the initial and final nodes of the arc) the coordinates of the arc center are recorded. Then the data column is located specifying the type of the arc where **0** corresponds to a simple arc, and **1** - to a transformer arc.

Apart from this, coordinates of the initial and final nodes in the arc are located instead of four columns describing the types and national identity of the initial and final nodes of the arc.

All comments elucidating the structure of this file are given in its title and table heading. To save space, this file is not given here in full (because it has slight differences with the **“el_net.out”** file).

File beginning

Line types:

transformer 1

simple line 0

coordinates types nodes

N	x	y	T	x	y	x	y	name_1	name_2
1	1254	1110	1	1276	1113	1232	1107 =>	540	541
2	1319	1142	0	1276	1113	1362	1170 =>	540	520
3	1225	1138	0	1232	1107	1218	1169 =>	541	542
4	1256	1168	0	1218	1169	1294	1166 =>	542	543
5	1250	1187	0	1218	1169	1282	1205 =>	542	544
6	1341	1183	0	1294	1166	1387	1200 =>	543	521
7	1335	1203	0	1282	1205	1387	1200 =>	544	521
8	1375	1185	1	1362	1170	1387	1200 =>	520	521
9	1393	1214	0	1387	1200	1399	1227 =>	521	200
10	1309	1218	1	1399	1227	1218	1209 =>	200	130
11	1194	1204	0	1218	1209	1169	1198 =>	130	120
12	1176	1171	1	1169	1198	1182	1144 =>	120	124
.....									
.....									
64								

End of the file

The list of transformer arcs in this test problem is as follows:

540_541, 520_521, 200_130, 120_124, 210_140, 60_61, 500_251, 500_250,
250_258, 270_150, 30_31 , 45_46, 40_42, 52_50, 50_51 , 10_12.

Getting Help

To get Help you should point to the **HELP** button in the left upper corner of the working window and press the left mouse button.

Quitting Help

To quit help you should press the left mouse button.

Scrolling the Working Window Module

On the left lower side of the screen there are control buttons of the working window scrolling. On the right the whole working area is displayed provided in the computer memory for creating the energy system. On this area there is a small square indicating the current location of the working window, i.e. the area accessible at the moment for operation with the energy system. Due to scrolling you can introduce changes in the energy system without special saving of the working area of the energy system building model. If the arc does not go in the working area, then it will be displayed as a thinner line.

Quitting the module

To quit the **SETTING FLOW DIRECTION** module. you should point to the **EXIT** button and press the left mouse button.

An image on the screen should appear comprising three buttons that describe possible alternative actions of the user:

“RETURN TO THE PROGRAM”

“SAVE & EXIT”

“EXIT”.

Point to one of the three buttons and make a choice pressing the left mouse button.

If you chose the **RETURN** button, you return to the working window of the **SETTING FLOW DIRECTION** module (Figure 2).

If you chose the **EXIT** button, then the **Network in Indexes 1** module will remain unchanged. If you chose the **SAVE & EXIT** button, then all changes in the configuration of the calculation scheme and changes of directions of connections among nodes will be introduced in the

Network in Indexes 1 file. In addition, the **lines.out** file will be created with the data on the types of arcs in the calculation scheme.

However in some cases **SAVE & EXIT** does not work, and the user will return to the editing of the scheme.

The matter is that the algorithm that makes a primary check of the calculation scheme correctness will start automatically, being latent for the user. Dubious nodes on the scheme will be designated by question marks. Possible ways out of this situation are: 1) to adjust directions of arcs; and 2) to exit this module without saving and to reassign the types of the nodes in the previous module because nodes of different types can locate on one and the same coordinates.

9. Data Entry Module

The **DATA ENTRY** module is intended to enter data (numerical values) for all nodes (objects) of a calculation scheme of an electric power network. In terms of design this module consists of two executable programs **R_1_EN.EXE** and **R_22E.EXE** executed sequentially.

The **DATA ENTRY** module can work correctly only if the work of previous modules (**CREATING NETWORK** and **SETTING FLOW DIRECTION**) is carried out, because it uses information of the output file "**Network in Indexes 1**"-**el_net.out** and **lines.out**. In the process of executing the **DATA ENTRY** module, the output files **el_net.out** and **lines.out** remain unchanged.

The **DATA ENTRY** module works only if there is - **egavga.bgi**

These modules **R_1_EN.EXE** and **R_22E.EXE** start working when the user presses the left mouse button pointing to the **DATA ENTRY** button. The first module operates automatically without the user's participation. Its major objective is to form the **list_en.out** file. Basing on the data of the **klav.out** file, the module automatically assigns internal names to all nodes included in the electric network by adding an ordinal number of this node type to the letter that characterizes the node type in the **el_net.out** file. The complex adjusts internal names assigned by this module in accordance with external names defined by the user. A table in the **list_en.out** text file includes external and internal names with their correspondences.

The Structure of Output File *Network in Indexes 2*

The **Network in Indexes 2** - **list_en.out** output file contains full information on the created scheme of the energy network. The first line of the file contains statistical parameters of the calculated energy network. Digits in the first line of the file show the total number of nodes in the calculated network and the number of nodes of each type:

- The first digit shows the number of simple nodes in the calculated network
- The second - the number of HEP
- The third - the number TEPP

- The fourth - the number of consumers
- The fifth - the number of balance plants
- The sixth - 0 (backup place for further updating)
- The seventh - 0 (backup place for further updating)
- The eighth – 0 (backup place for further updating)
- The ninth - the total number of nodes in the calculated network.

Next lines of the file from the second line to N+1 (where N is the number of nodes in the calculated scheme) contain information on each node in the calculated network:

- The first digit in the line - consecutive numbering of nodes.
- The second and the third digits in the line - coordinates of a node (x, y) on the screen.
- The fourth digit in the line - numerical index of a node type.
- The fifth digit in the line - numerical index of national identity.
- The sixth digit in the line - ordinal number of a node for the nodes of one type. This ordinal number for nodes of each type is set automatically, as the **R_1_EN. EXE** module is executed.
- Then, the letter index of the node type with the ordinal number of the node.
- Then, division symbol “ | ”.
- The external name of the node follows the “ | ” division symbol.

Between each digit, there should be at least one space.

The **Network in Indexes 2** file first describes simple nodes of the calculated network, then it describes HEP, TEPP, consumers, and balance plants.

Below we give the full text of the **Network in Indexes 2** file formed for our problem.

```

      8 0 6 36 1 0 0 0 51
1 1276 1113 1 1 1 K1 540 _____
2 1399 1227 1 1 2 K2 200 _____
3 1404 1253 1 1 3 K3 210 _____
4 1434 1352 1 1 4 K4 66 _____
5 1405 1109 1 1 5 K5 500 _____
6 1105 1298 1 1 6 K6 270 _____
7 1479 1283 1 1 7 K7 30 _____
8 1576 1439 1 1 8 K8 52 _____
9 1163 1102 3 1 1 H1 124 _____
10 1270 1349 3 1 2 H2 61 _____
11 1433 1141 3 1 3 H3 251 _____
12 1340 1093 3 1 4 H4 258 _____
13 1543 1211 3 1 5 H5 31 _____
14 1483 1399 3 1 6 H6 51 _____
15 1232 1107 4 1 1 U1 541 _____
16 1218 1169 4 1 2 U2 542 _____
17 1294 1166 4 1 3 U3 543 _____
18 1282 1205 4 1 4 U4 544 _____
19 1387 1200 4 1 5 U5 521 _____
20 1218 1209 4 1 6 U6 130 _____
21 1177 1181 4 1 7 U7 120 _____
22 1144 1236 4 1 8 U8 140 _____
23 1138 1179 4 1 9 U9 100 _____
24 1157 1316 4 1 10 U10 90 _____
25 1140 1379 4 1 11 U11 80 _____
26 1227 1315 4 1 12 U12 70 _____

```

27	1364	1316	4	1	13	U13	46
28	1364	1355	4	1	14	U14	60
29	1410	1060	4	1	15	U15	250
30	1482	1102	4	1	16	U16	240
31	1469	1175	4	1	17	U17	220
32	1590	1053	4	1	18	U18	241
33	1600	1124	4	1	19	U19	10
34	1591	1243	4	1	20	U20	20
35	1108	1065	4	1	21	U21	280
36	1107	1343	4	1	22	U22	150
37	1081	1343	4	1	23	U23	162
38	1079	1427	4	1	24	U24	161
39	1121	1428	4	1	25	U25	160
40	1193	1395	4	1	26	U26	58
41	1198	1437	4	1	27	U27	57
42	1584	1289	4	1	28	U28	21
43	1537	1321	4	1	29	U29	45
44	1531	1372	4	1	30	U30	40
45	1385	1438	4	1	31	U31	50
46	1408	1393	4	1	32	U32	56
47	1323	1389	4	1	33	U33	55
48	1127	1134	4	1	34	U34	110
49	1481	1353	4	1	35	U35	42
50	1541	1089	4	1	36	U36	12
51	1362	1170	5	1	1	B1	520

The user can access this file, probably for editing, through the main menu by pressing the left mouse button and using the Network in Indexes 2 - list_en.out button.

The DATA ENTRY module (part R_22E.EXE) creates a group of files that contain information about the data entered. For the data entered, a separate file is created for each node type. If you did not enter numerical values for some node, then these values are adopted by default.

The table shows filenames that form depending on a node type as data are being entered (values for a given node type adopted by default).

- **Internal name** (which is an index characterizing the node type and its ordinal number in the scheme).

File title	Filename	Data entered by default
Simple nodes	simple.in	0.00
HEP	hydro_st.in	0.00
TEPP	heat_st.in	0.00
Consumers	user_e.in	0.00
Balance plants	balans.in	0.00
Time step	steps_e.in	0.00
Time step length	time_e.in	4 - month index
Data on lines	duga.in	0.00

The **DATA ENTRY** module performs the following operations:

- Assigns a number of time steps.
- Assigns a type of time steps.
- Enters a number of seconds in every time step.

- Enters necessary data for the **Simple** nodes.
- Enters necessary data for the **HEP** nodes.
- Enters necessary data for the **TEPP** nodes.
- Enters necessary data for the **Consumer** nodes.
- Enters necessary data for the **Balance Plant** nodes.
- Enters necessary data for simple lines of electric power transmission.
- Enters necessary data for transformer lines calculation.

Note: The coefficients to take into account the losses in the lines and nodes are entered million times higher than they are actually. However in the tables these coefficients are located in their actual format.

The **DATA ENTRY** module is started as follows. In the interface, point to the **DATA ENTRY** button and press the left mouse button. An image (Figure 4) will appear on the screen. It consists of a working area with a calculation scheme of the energy network, a toolbar with buttons and dialog boxes above the area, an area for the data entry tables on the left, and a scrolling block on the right bottom side - to scroll the working area on the screen. If you point to any node, then you will see the features of this node in dialog boxes.

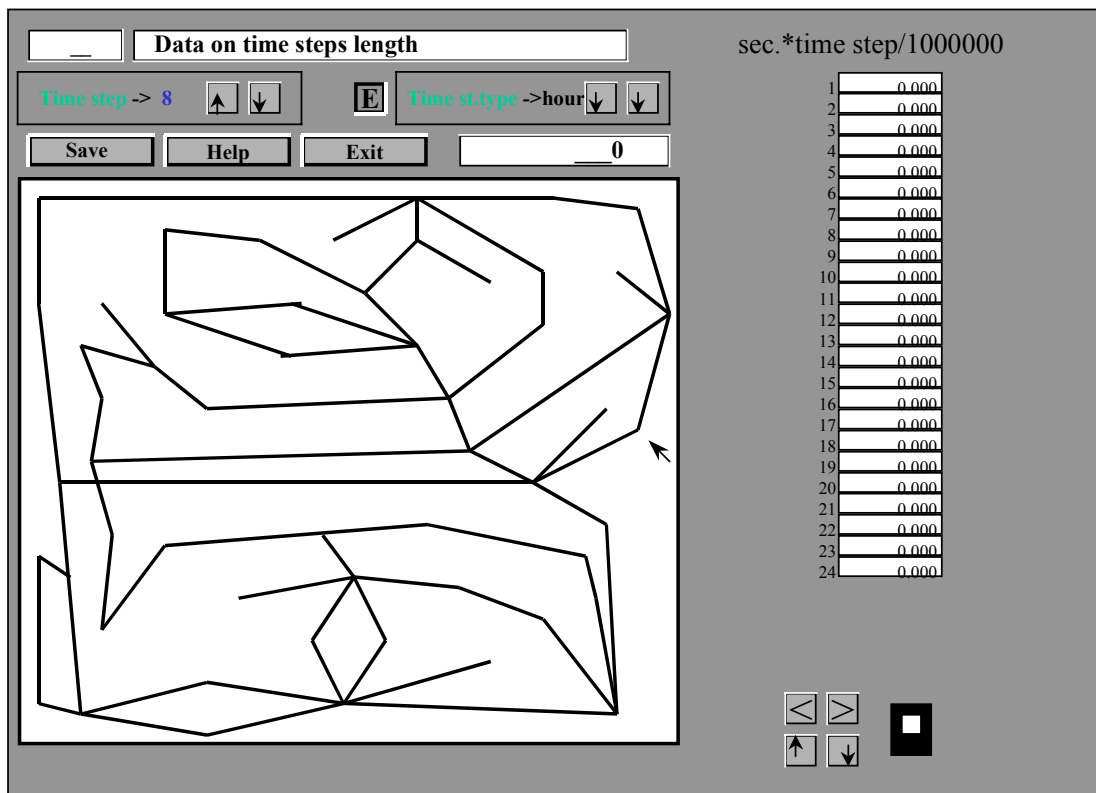


Figure 4. Screen view in the mode of data entry into nodes and arcs of the energy network (time steps).

On the lines there are crosses and red squares. Crosses are the symbols of a simple line of electric power transmission while squares indicate a transformer line.

Two dialog boxes of the upper bar located in the top line of the screen display: the national identity of the node and the external name of the node.

The dialog box located in the third line of the toolbar displays the node type and its ordinal number (**list_en.out**) in the calculated electric energy network.

The toolbar (second line from above) includes two blocks:

- Buttons to enter the number of time steps
- Buttons to enter the type of time steps

Assigning Number and Type of Time Steps

By default the block of entering the number of time steps is disengaged, and if you press buttons with arrows (↑↓), then they will not change the number of time steps.

To set a number of time steps, you have the area for entering the number and type of time steps. For this purpose there is a special **E** button located in the upper part of the screen, in the second line, and a block of entering a number of time steps and their types located on both sides on this button.

The maximum number of time steps is **24**. You can define four types of time steps: month, ten-day period, day, hour.

When the **E** button is pressed, the scheme on the working area is not active; therefore, you cannot enter data for scheme nodes.

To activate the block of entering the number and type of time steps, you should click the left mouse button on the **E** button. It will "sink" visually, and you can change the number and type of time steps using the (↑↓) buttons on both sides of button **E**.

After you have completed entering a number of time steps, click the left mouse button on the **E** button to disengage the block of entering time steps and to activate a calculation scheme on the working area. At this moment, the set number of time steps and their type with the length of every time step are recorded in the "**steps_e.in**" and "**time_e.in**" files.

Fig. 4 shows the menu of the **DATA ENTRY** module in the mode of defining a number and type of time steps. On the right-hand side there is a table including 24 cells. The user can introduce in every cell a number of seconds for every time step divided by one million. You can move through the cells with the command keys. Moving within a cell can be performed with the command keys with simultaneous pressing of the **CTRL** key. You cannot leave a cell, if you don't complete correctly a number entry. Number entry is completed either by pressing the **ENTER** key, or by moving from the cell to an adjacent one.

Entry of Parameters for Nodes in Arcs

To enter parameters in a node of any type, you should activate corresponding tables of data entry. You achieve this mode only when the **E** button is pulled. Point to the node on the calculation scheme. At that individual messages on the screen will change in accordance with the type of the node pointed:

- Green pointer should appear near the node.
- In the national identity dialog box you will see an abbreviated country name (for our test problem **Taj**).
- In the external name dialog box you will see an external name assigned to the node.
- In the node type dialog box you will see a type and an index ordinal number of the node.
- In the area of data entry tables corresponding tables of data entry will appear for nodes of different types: for the **Consumer** node - Figure 5; for the **Generators** node (HEP, TEPP, Balance plants) - Figure 6; for **Simple** node - Figure 7; and for electric power transmission lines (simple lines and transformer lines) - Figure 8.

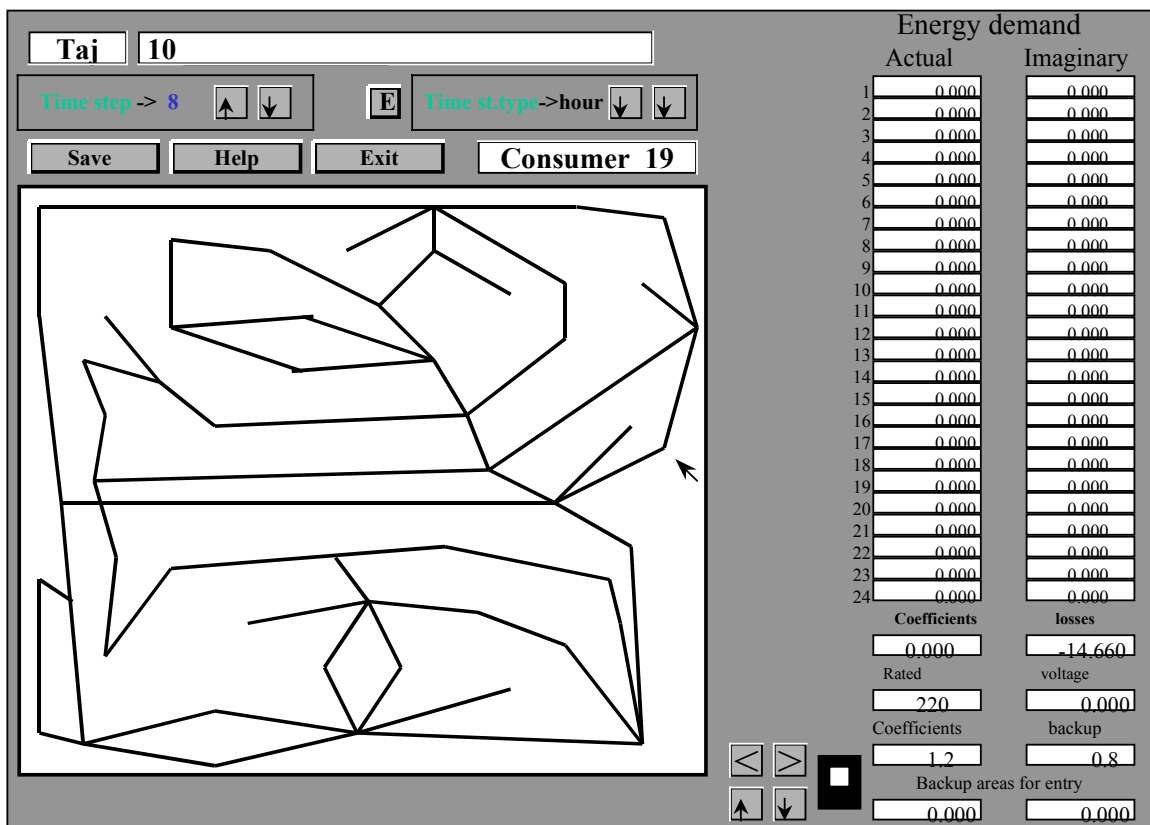


Figure 5. Screen view in the mode of data entry into the nodes and arcs of the energy network (user).

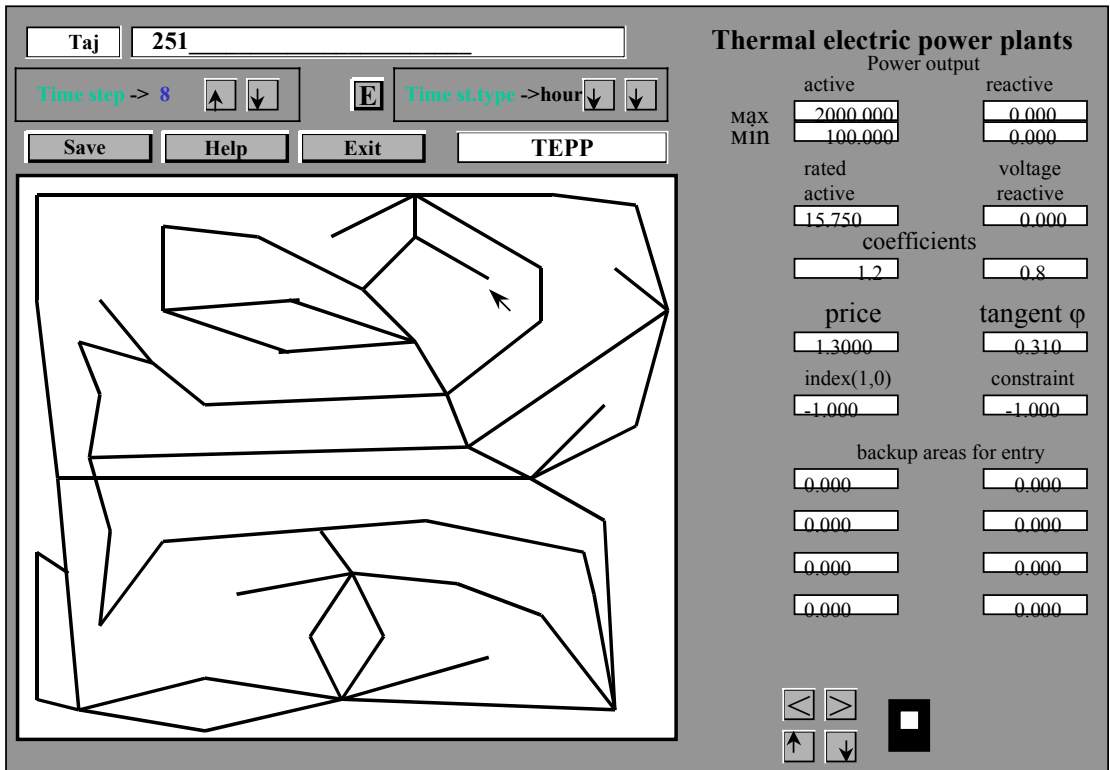


Figure 6. Screen view in the mode of data entry into the nodes and arcs of the energy network (generators).

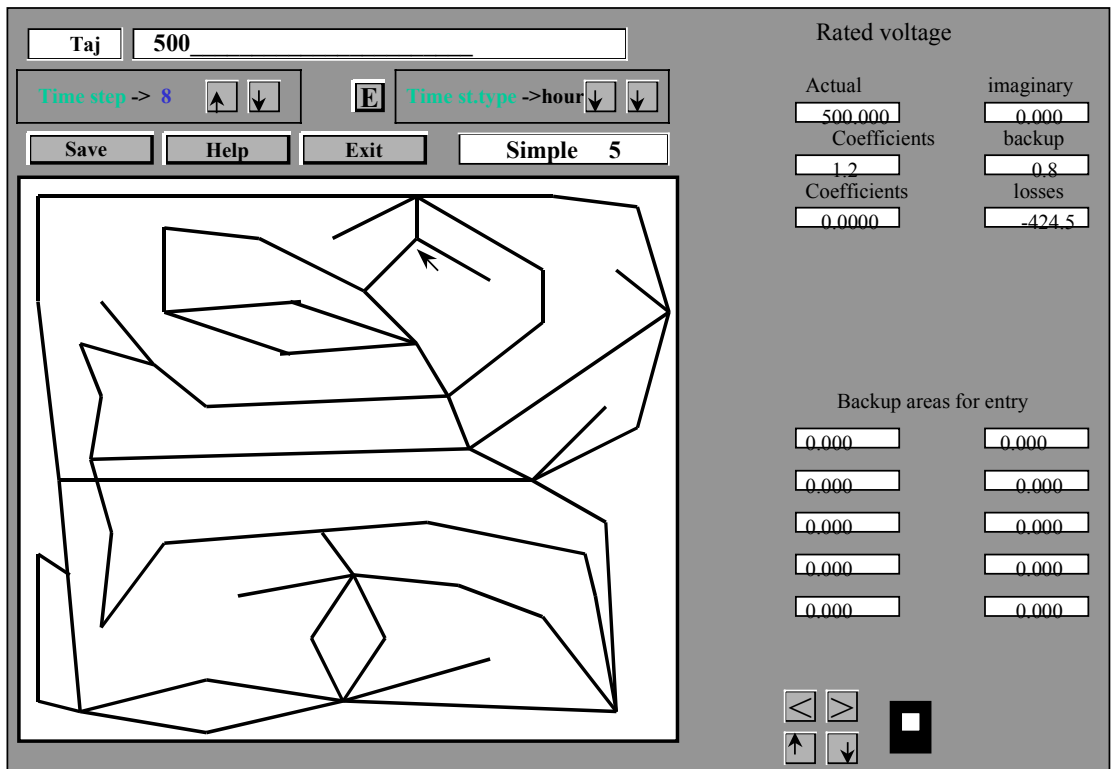


Figure 7. Screen view in the mode of data entry into the nodes and arcs of the energy network (simple nodes).

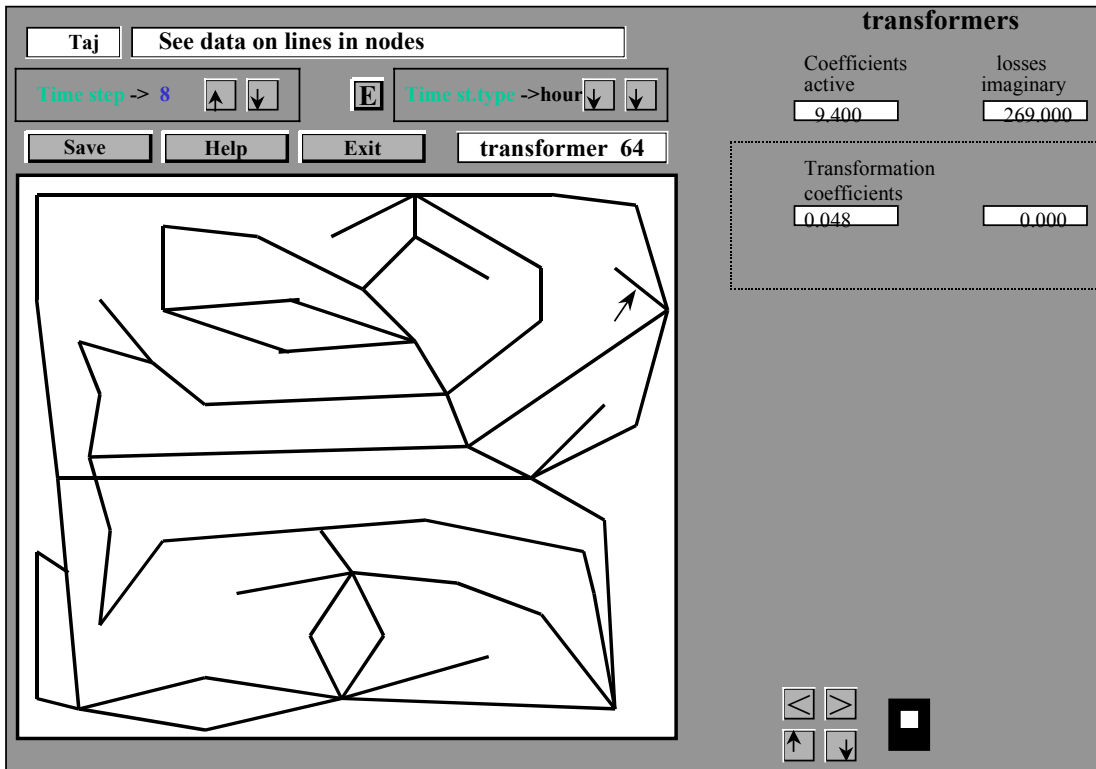


Figure 8. Screen view in the mode of transformers data entry (and simple lines data entry).

Data are entered in tables. If the white pointer indicating the position, where the entered digit appears, is located in a wrong table or cell, then you can move it to the cell you need using command keys on the keyboard (\uparrow , \downarrow , \leftarrow and \rightarrow). The pointer marks the entry position, which changes as the user presses command keys \leftarrow or \rightarrow and the **Ctrl** key simultaneously. Until entry completion all other operation modes are dead. The user completes entering a digit by pressing **ENTER** or leaving the area of the entered digit. If the user cannot go to another entry cell, it means that the complex cannot interpret the digits entered, and therefore the user has to correct these digits.

The Structure of Output File *Time Steps*

The **Time Steps-steps_e.in** output file contains information on the number of time steps adopted in calculation, and the type of time steps. Data are given in numerical indexes.

Below we give the full text of the **TIME STEPS-step.in** for our test problem.

No. of Line	Data Given in Each File Line	
First line	file	number of time steps (1->24) hour-1,day -2, ten-day period-3, month -4 (1->4)
Second line	file	8 1

The first file line is a comment line. In it, we describe the meaning of numerical indexes adopted in this package of programs. These numerical indexes are located and used in the second line of the **Time Steps** file.

The first digit of the second line of the file displays the number of time steps.

The second digit of the second line is the numerical index of the type of the time step (**1** – for time step **hour**; **2** – **day**; **3** - **ten-day period**; **4** - **month**).

Structure of Output File *Time Step Length time_e.in*

The output file comprises 4 lines. The first three lines are comment lines; the last line includes the entered data on number of seconds in a time step divided by one million.

No. of file line	Data given in each file line	Note
1	First three lines - comment lines; Line 4 - values of coefficients	Comment
2	Every digit is a number of seconds in the time step divided by one million	Comment
3	Value	Comment
4	0.0036 0.0036 0.0036 0.0036 0.0036	

Structure of Output Files for the *Generator* Nodes (HEP, TEPP, Balance Plants)

Output files **Generators - hydro_st.in heat_st.in** и **balans.in** have similar structures as follows: the first file line, which is a comment about the file, is followed by digit blocks of 10 lines each.

In the first file line, the first digit is the number of nodes of a given type and so of the blocks in the calculation scheme. Further the comment follows. The number of blocks equals the first digit in the first file line.

In the first line of the block

- Digit means the ordinal number of the **Generators** node in the calculation scheme and correspondingly the number of the block.
- Next two digits are coordinates of a given node in the calculation scheme.
- Then, the => symbol should follow.
- Next the external name of the node - source of electric power - is given.

The second line of the block includes comments.

The digit area of each block consists of two columns:

The **Generators** output files have the following structure.

No. of block	No. of block line	Data given in each file line
		6 Data on Thermal Electric Power Plants
Block 1	1	1 1163 1102 => 124
	2	energy max/energy min/voltage/ coeff max, min/ price Tg /losses / constraints
	3	198 0.00 max power output (actual and imaginary part)
	4	10 0.00 min power output (actual and imaginary part)
	5	10.5 0.00 rated voltage (actual and imaginary part)
	6	1.1 0.80 coefficients to define allowable deviation from the rated voltage to increase and to decrease
	7	1.1 0.85 unit price of power and Tg Fi
	8	0 0.00 if the first number is above zero, then the second digit defines the upper constraint on power output for a given plant for the entire period of calculation, and the plant will gain the status of a limited plant. In the test problem there is only one plant of this type - 520
	9	0.00 0.00 backup areas for further updating of the program
	10	0.00 0.00 backup areas for further updating of the program
	11	0.00 0.00 backup areas for further updating of the program
	12	0.00 0.00 backup areas for further updating of the program

- First, second and third digits of the second column in the test problem are not used.

These digits can be used when solving more complex problems connected with optimization of complex energy transfer.

All files “**Hydro_st.in**” “**Heat_st.in**” “**Balans.in**” have identical structure and differ only in the comment in the top line.

Structure of *Consumers* Output File

The output file **Consumers** - “**user_e.in**” has the following structure:

The first file line, which is the main comment on the file content, is followed by blocks of 30 lines each.

The structure is best seen in an example.

No. of block	No. of block line	Data given in each file line
Block 1	Block line 1	1 1232 1107 => 541_____
	Block line 2	active reactive request/
	Block line 3	1 50.0 20
	Block line 4	2 50.0 20
	Block line 5	3 50.0 20
	Block line 6	4 50.0 20
	Block line 7	5 50.0 20
	Block line 8	6 50.0 20

	Block line 26	24 50.0 20
	Block line 27	0 -0,00009050 Actual losses. Complex
	28	220 0,00 Rated voltage
	Block line 29	220 0,00 coefficients of deviations from rated voltage
	Block line 30	38 0,00 backup areas for digits entry

The package of programs works so that only the first N+2 lines of each block of the output file **Water Diversion** (N is the number of set time steps) and lines 27-30 of each block.

Structure of Output File *Simple Nodes*

The output file **Simple Nodes** - “**simple.in**” has the following structure:

The first file line, which is the full title of the file, is followed by blocks of 10 lines each.

In the first file line the first digit is the number of **Simple** nodes in the calculation scheme.

The block structure is best seen in an example.

No. of block	No. of block line	Data given in each file line
	Block line 1	1 1276 1113 => 540_____
	Block line 2	/Voltage (active, reactive), coefficients (max, min), losses (active, reactive), backup
	Block line 3	500 0.00 rated voltage (active, reactive)
	Block line 4	1.2 0.80 coefficients of possible deviation from rated voltage
	Block line 5	0 -0.00036500 coefficients of active and reactive losses
	Block lines 6-10	0 0.00 backup lines

Structure of Output File of *Simple and Transformer Lines*

The output file **Lines-“duga.in”** contains parameters necessary to calculate energy losses in transfer and voltage transformation .

The output file **“duga.in”** has the following structure: the first file line, which is the digit of the blocks number (coinciding with the lines number in the electric power network) and general comments, is followed by blocks of 4 lines each.

```
1  1  52 1254 1110 => <= coordinates of the center of the transformer line
  / coefficients of losses (actual and imaginary) / coefficient of transformer + backup area
    0.9700000000    61.0000000000
    0.4600000000    0.0000000000
```

In the first block line: The first digit is index of the line identity to a transformer arc. We have a simple line at digit **0**, and a transformer line at digit **1**. Next digit is the ordinal number of the line coinciding with the ordinal number from the **el_net.out** file. The following digit is an internal counter of the program acting here as a comment. Then after the **<=** symbol the coordinates of the center of the electric power line and its name follow.

The second block line contains brief comments on the meaning of digits in the third and fourth block lines.

In the third block line:

- the first digit is coefficient of losses (actual part)
- the second is coefficient of losses (imaginary part).
-

In the fourth block line:

- the first digit is coefficient of transformation
- the second digit is a backup area for further program updating.

It is clear that the fourth line is taken into account only in cases when this line is of the transformer type. An example of a block is given below.

No. of block	Номер строки блока	Data given in each file line
		1 Calculation of losses (+) or infiltration (-) [L, k] Losses = $L * K * E(i)$
Block 1	Block line 1	1 1 52 1254 1110 => <= coordinates of the line center
	Block line 2	/ coeff. of losses (actual and imaginary) / coeff. of transform. + backup area
	Block line 3	0.97 61.0
	Block line 4	0.46 0.00

The package of programs works so that only comments in each block vary slightly depending on the line type (simple or transformer).

10. Creating GAMS Model Module

Composition and Structure of the GAMS Model

Constructively this model includes three interacting and isolated files that contain the text of the model of optimal electric power management. This model is recorded under the rules of the GAMS compiler.

The first part is devoted to definition of all parameters and initial data that determine a specific calculation problem.

The second part is actually the most universal part of the model including equations.

The third part is a file with the procedure of delivering a calculated result to an individual file.

To solve a raised problem, each of these parts should be available.

The model built is runnable in the directory where it was built. It loses its operability if it is recorded in a different directory because paths to the model's components cease conforming to the new location of the model. To restore the model's operability it is necessary to find path specifications in the model and change them according to the new location (or to delete them completely). Here we mean the following paths:

- The path to the **equation.prn** block specified in the **electro.gms** file
- The path to the **output.prn file**; the path to the **electro.out** file.

Operation of the Module for Automatic Creation of the GAMS Model

To run this module, the user should point at the **CREATING GAMS MODEL** button and press the left mouse button. The **build_e.exe** module will be activated.

Most testings of the model building process are connected with the specifics of the **GAMS** language, and therefore situations, where the user has to correct an error while he operates the mode of editing the constructed model, may occur.

The only question that the user will be asked is the necessity to update the equation block as the model is created. If the user does not want to update the equation block, then a previously created block remains in the model. Such an independent creation of blocks allows the user to conduct research of the created model changing and updating the equation block for his specific

tasks. At the beginning of this Manual we provide the text of the **GAMS** model automatically created by the model construction module.

Implementation of Optimization Calculations of the GAMS Model

To start the GAMS compiler, you should point at the **CALCULATION** button and press the left mouse button. At that the **GAMS electro.gms** command line is formed and executed. Messages of the GAMS compiler will appear on the screen, and the user should trace the appearance of the inscription **OPTIMAL SOLUTION FOUND**. Only after this inscription has appeared, the user can undertake actions associated with translation and formation of output calculation forms. Otherwise, these forms may either not work or contain wrong data. The appearance of the **OPTIMAL SOLUTION FOUND** inscription means that the energy balance for the entire system created and electricity laws meeting are kept precisely.

Access to the Main File of the GAMS Model Text

The user can get access to each file comprising the “**equation.prn**” “**electro.gms**” “**output.prn**” model through a corresponding button on a main control panel window (Figure 1).

Access to the Main Output File of the GAMS Compiler

In the process of the GAMS compiler operation, the **electro.lst** file automatically forms. This file has all information about calculation process, including that about errors of testing the program body. All compilation errors are marked with four asterisks going in sequence.

The user can see the contents of this file if he presses the left mouse button at the moment when the mouse pointer is at the **electro.lst** menu button.

Having detected and identified an error, the user can correct directly in the model text or through making corrections using previous modules described above.

Access to the File of Calculation Results of the GAMS Model

Pointing to the **OUPUT RESULT** button and pressing the left mouse button, the user gains access to the file of calculation results of the model to assess the solution obtained.

Despite our attempt to present results in tabular forms convenient for perception, you can learn how to assess results quickly only after some practice. This primarily relates to the fact that information about obtained solutions is displayed only for internal names used in the GAMS model. Access to a separate file that forms output in the **outpur.prn** model enables the user to form a convenient and perceptible data output.

11. Translation of Calculation Results to Other Languages

The GAMS compiler works only with letters of the Latin alphabet, and that causes problems of readability of output forms. In addition, internal names given by the complex to nodes of the calculated scheme impede the reading and interpretation of results. To solve this problem, we created the module of the results translator.

The translator of the results is the `TRANSL_E.EXE` module that handles the main files of results `electro.out`.

Unlike other modules, this module is operable only if it is started through creating a command line containing three sequential parameters.

For example: `TRANSL_e.EXE c:/model/ c:/model/test 7 for electro.out`

The first parameter shows the location of the internal complex dictionary, the second parameter shows locations of files for translation and using the internal dictionary of the complex replaces English terms with their analogs from the internal dictionary `diction.el`. To make edition of this dictionary, there is a special button on the main control panel window of the complex (Figure 1). In addition, the translator uses the `list_en.out` file, basing on which it changes the internal names of the GAMS model to external ones. The external names were given by the user when building the electric power network.

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