APPENDIX 2. DESCRIPTION OF THE MODELING SYSTEM FOR ENERGY MANAGEMENT PROBLEMS

Contents

1. The Elements and Structure of the *Energy* Model's Database

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- *Name of the Power System*
- *Data Reception Sign (Layout, ROBCOM)*
- *Data Transfer Sign*

1.2 Power Complexes Data
- *Number of a Power Complex*
- *Name of a Power Complex*
- *Data Reception Sign*
- *Data Transfer Sign*
- *Maximum Power Consumption*
- *Minimum Power Consumption*
- *Maximum Load of Uncalculated Power Stations*
- *Minimum Load of Uncalculated Power Stations*

1.3 Calculated Power Stations Data
- *Number of a Power Station*
- *Name of a Power Station*
- *Number of the Node to Which a Power Station Belongs*
- *Type of a Power Station (Hydroelectric Power Station, Thermoelectric Power Station)*
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- *Number of a Power Station in the Library of Consumption Characteristics*
- *Data Transfer Sign*

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- *Name of a Node*
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On-Line Information

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1.15 Data on Constraints on Balance Transfers of Power Systems for a day

2. Consumption and Load Data for Kazkh Power Stations

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== "Full name and telephone number of the person responsible for data preparation"))

Where:

Code	***Name***		***Requisites***
(8)	Almaty Power Complex	1-24	Hourly Consumption
		25-48	Hourly Load of Uncalculated Thermoelectric Power Stations
		49-72	Hourly Load of Uncalculated Hydroelectric Power Stations
(6)	Chimkent Power Complex	1-24	Hourly Consumption
		25-48	Hourly Load of Uncalculated Thermoelectric Power Stations
(7)	Jambul Power Complex	1-24	Hourly Consumption
		25-48	Hourly Load of Uncalculated Thermoelectric Power Stations
(16)	Chardara Power Complex	1-24	Hourly Consumption
(18)	North Kazakhstan Power Complex	1-24	Hourly Consumption of North Kazakhstan
		25-48	Hourly Load of North Kazakhstan

ммдд – date (month, day) of data submission.

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==КККК:
"I. D. Ametov.           ==))
```

Where:
ммдд = date (month, day) of covered daily schedule;
XXXX = hourly data;
CCCC = daily data;
КККК = check sum.

3. Developing and Testing the Energy Model

Developing and Testing the* Energy *Model

In accordance with the TOR, the model was developed stagewise with the consecutive realization of two variants of the mathematical model.

Variant 1, which was simpler, envisaged daily planning of the EPP CA mode proceeding from the condition of optimizing EPP CA modes every hour individually regardless of integral daily constraints.

Variant 2, which was more complex and size-intensive, envisaged optimizing hourly EPP modes proceeding from the condition of optimized daily indicators. The indicators included minimized total daily costs of the EPP CA to purchase power from thermoelectric and hydroelectric power stations, power generation by stations and balance transfers of active power of power systems. In addition, Variant 2 included additional integral daily constraints on consumption of energy resources by power stations.

Both variants were independent enough in terms of realization and practical application.

Both model variants underwent consecutive testing, first on a simple electric circuit, then on the EPP CA's real equivalent circuit used in UDC Energia for operational planning of EPP CA modes.

At the first stage, we formed each variant of the GAMS model manually. Then, we thoroughly tested it on a simplest example and refined it to obtain positive calculation results.

The next step for each variant was modernizing the OPTIMUM complex to develop and include program modules to form the GAMS model, start it, and transfer output data. After that, we tested the complex modified for the real circuit and data.

As a simplest reference circuit to test all variants of GAMS models, we used the circuit showed on Figure 1.

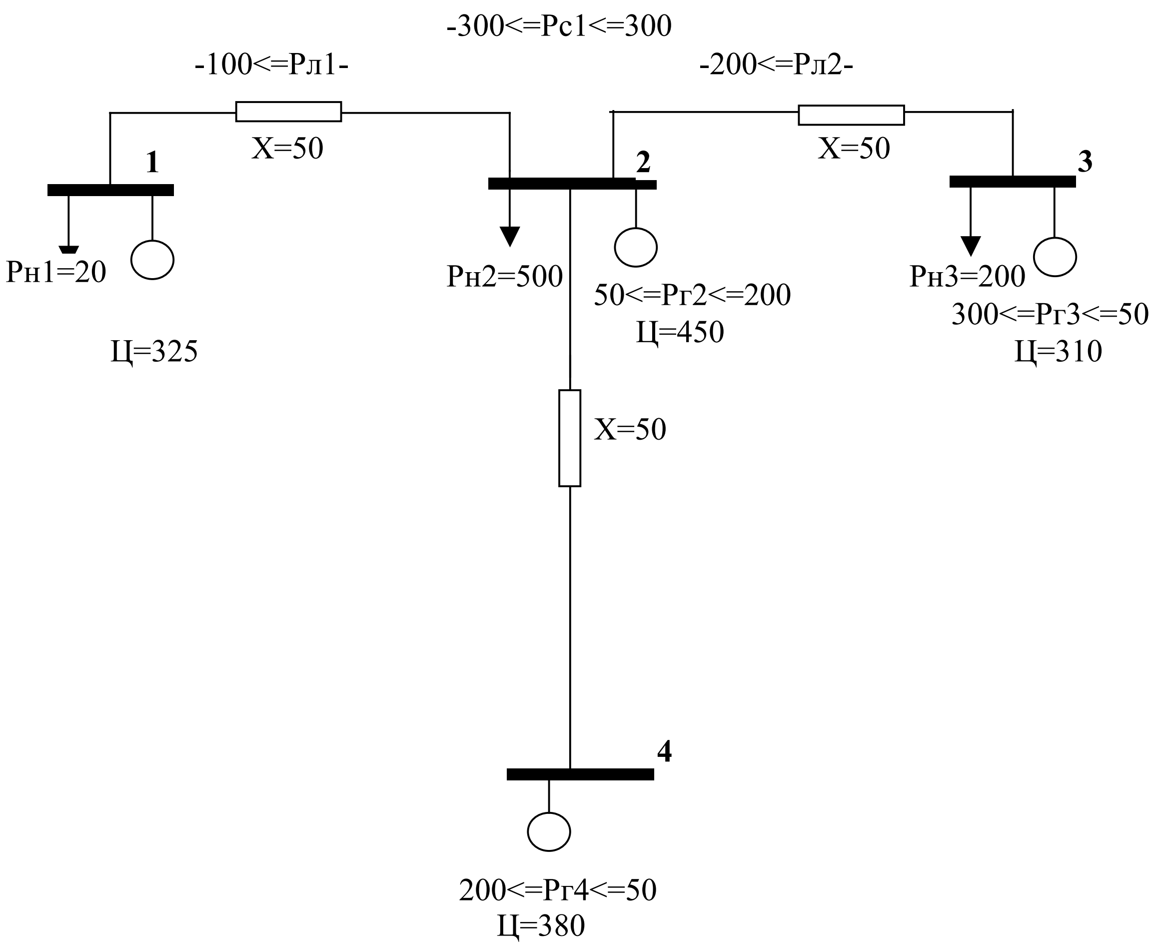

Figure 1. Design Circuit

The circuit shows 4 power stations (nodes 1, 2, 3, and 4) and 3 consumers (nodes 1, 2, and 3). To each power station we assigned the sale price of electric power (Ц) and available active power in the form of boundary values (<=P1г <=, <=P2 г <=, <=P3 г <=). Consumers are assigned through a fixed active load (Pн1, Pн2, Pн3).

In the circuit, transmission lines are assigned by reactance (X=50 ohm). Constraints on direct and reverse active power transfers (<=Pл1-2<=, <=Pл2-3<=, <=Pл4-2<=) are assigned to all 3 lines. Besides, we assigned a constraint on direct and reverse active power transfers of the section of lines 1, which defines the total transfer of active power over lines 1-2 and 2-3 (Pсеч1).

All specified data are shown directly on the circuit.

Testing Variant 1 of the Model

In the process of developing variant 1 of the GAMS model underwent several modifications. Below we give the initial GAMS model variant fully corresponding to the TOR. The GAMS model is presented in the form of the following set of files:

Odc*opt01.gms ((head file of the model))*

```
$include c:\Gams\Odcset01.txt
$include c:\Gams\Odccon01.txt
$include c:\Gams\Odctab01.txt
$include c:\Gams\Odcequ01.txt
```

Odcset01.txt (file of variables)

```
sets
 g  /g01*g04/   # indexes of calculated power stations
 ol /l01*l03/   # indexes of reference lines
 os /s01/              # indexes of reference sections
 k / balans /   # index of the power balance for the whole circuit
        ;
```

Odccon01 .txt (file of constants)

```
 Parameters

   c(g)                          # sale price of electric power of calculated power stations
    /   g01  325
        g02  450
        g03  310
        g04  380
              /
  pgmin(g)                       # minimum load of calculated power stations
    /   g01  50
        g02  50
        g03  300
        g04  200
              /
```

```
  pgmax(g)                              # maximum load of calculated power stations
     /   g01  200
         g02  200
         g03  500
         g04  500
                /
   oglp(ol)                     # assigned constraints on direct transfer over controlled lines
     /   l01   100
         l02   200
         l03   300
                /
    oglo(ol)                    # assigned constraints on reverse transfer over controlled lines
     /
         l01    100
         l02    200
         l03    300
                  /
    ogsp(os)                    # calculation constraints on direct transfer over the section of lines
     /
         s01    550
                /
    ogso(os)                    # calculation constraints on reverse transfer over the section of
lines
     /
         s01     50

                /
    bal(k)                              # constraints on power balance in the circuit
      /  balans    300  /
    ;
```

______________________________***Odctab01 .txt (file of tables)***

```
Table a1(g,ol)                  # table of distribution coefficients of controlled lines
l01     l02    l03
     g01     0.78    0.22   0.0
     g02    -0.22    0.22   0.0
     g03    -0.22   -0.78   0.0
     g04    -0.22    0.22   1.0


 Table a2(g,os)                         # table of distribution coefficients of controlled sections

          s01
     g01     1.0
     g02     0.0
     g03    -1.0
```

```
   g04     0.0
```

______________________________*Odcequ01.txt (file of equations and results output)*

```
Variables
      f ;                                    # variable of the objective function


 Positive Variables x(g),                  # increments in power of calculated power stations
                  pg(g),              # resulting powers of calculated power stations
                  pkvl(ol), # resulting transfers over controlled lines
                  pksch(os),          # resulting transfers over controlled section;
Parameters
                  oglpr(ol),          # calculation values of constraints on direct transfer over lines
                  oglor(ol);          # calculation values of constraints on reverse transfer over lines

 oglpr(ol)  = oglp(ol) - sum(g, a1(g,ol)  * pgmin(g) ); # definition of calculated values of
constraints
 oglor(ol)  = oglo(ol) - sum(g, a1(g,ol)  * pgmin(g) ); # on lines

Equations                                        # equations
      cel                                    # objective function
      ogrlp(ol)                              # constraints on direct transfer over lines
      ogrlo(ol)                              # constraints on reverse transfer over lines
      ogrsp(os)                              # constraints on direct transfer over the section of lines
      ogrso(os)                              # constraints on reverse transfer over the section of lines
      bales(k)                               # constraints on power balance;

cel ..        f  =e=  sum(g, c(g)*x(g)) ;

  ogrlp(ol)  ..     sum(g,  a1(g,ol)  * x(g) )  =l=  oglpr(ol) ;
  ogrlo(ol ) ..     sum(g, -a1(g,ol)  * x(g) )  =l=  oglor(ol) ;
  ogrsp(os)  ..     sum(g,  a2(g,os)  * x(g) )  =l=  ogsp(os) ;
  ogrso(os)  ..     sum(g, -a2(g,os)  * x(g) )  =l=  ogso(os) ;
  bales(k)   ..     sum(g,  x(g) )  =e=  bal(k) ;

  x.UP(g) =  pgmax(g) - pgmin(g);     # constraints on the maximum load of a power station

  Model opt /all/ ;

  Solve opt using lp minimizing f ;

  Display x.l ;

                     # definition of powers of calculated power stations
  LOOP(g, pg.l(g) = x.l(g) + pgmin(g)) ;
```

```
                    # definition of power transfers over lines and line sections
  LOOP(ol, pkvl.l(ol)  = sum(g, a1(g,ol)  * pg.l(g) )) ;
  LOOP(os, pksch.l(os) = sum(g, a2(g,os) * pg.l(g) )) ;

FILE OPTRPS /result.dat/
PUT OPTRPS;

                    # output of constraints on power transfers of lines
PUT "-----oglpr:--------------"/;

PUT "L1="; PUT oglpr('l01'):8:2/
PUT "L2="; PUT oglpr('l02'):8:2/
PUT "L3="; PUT oglpr('l03'):8:2/
PUT /;
PUT "-----oglor:--------------"/;

PUT "L1="; PUT oglor('l01'):8:2/
PUT "L2="; PUT oglor('l02'):8:2/
PUT "L3="; PUT oglor('l03'):8:2/
PUT /;
                    # output of calculated power increments by power stations
PUT "-----delta PG:--------------"/;

PUT "PG1="; PUT x.l('g01'):8:2/
PUT "PG2="; PUT x.l('g02'):8:2/
PUT "PG3="; PUT x.l('g03'):8:2/
PUT "PG4="; PUT x.l('g04'):8:2/;
PUT /;

                    # output of maximum calculated powers of power stations and constraints
PUT "---------- PG:--------------"/;

PUT "PG1="; PUT pg.l('g01'):7:2 PUT " PMAX="; PUT pgmax('g01'):7:2/
PUT "PG2="; PUT pg.l('g02'):7:2 PUT " PMAX="; PUT pgmax('g02'):7:2/
PUT "PG3="; PUT pg.l('g03'):7:2 PUT " PMAX="; PUT pgmax('g03'):7:2/
PUT "PG4="; PUT pg.l('g04'):7:2 PUT " PMAX="; PUT pgmax('g04'):7:2/;
PUT /;

                    # output of calculated power transfers and constraints on lines
PUT "---------- PL:--------------"/;
PUT "PL1="; PUT pkvl.l('l01'):7:2 PUT " PP="; PUT oglp('l01'):7:2 PUT " PO="; PUT
oglo('l01'):7:2/
PUT "PL2="; PUT pkvl.l('l02'):7:2 PUT " PR="; PUT oglp('l02'):7:2 PUT " PO="; PUT
oglo('l02'):7:2/
```

```
PUT "PL3="; PUT pkvl.l('l03'):7:2 PUT " PR="; PUT oglp('l03'):7:2 PUT " PO="; PUT
oglo('l03'):7:2/
PUT /;

                    # output of calculated power transfers and constraints on the section
PUT "---------- SECH-------------"/;
PUT "PS1="; PUT pksch.l('s01'):7:2 PUT " PR="; PUT ogsp('s01'):7:2/
PUT /;
PUT "---------- CEL:--------------"/;
PUT "CEL="; PUT f.l:9:2/;
PUTCLOSE OPTRPS;
```

Note:
Coefficients of power distribution of calculated power stations along controlled lines (Table a1) and line sections (Table a2) are output data of the electric mode model. In this and all further models a corresponding program embedded in the OPTIMUM complex calculated these coefficients.
Testing the model given above, we considered three options of calculation conditions:

- With assigned joint constraints on power stations, lines and the section (option 1);
- With refusal to consider constraints on lines and the section (option 2);
- With initially incompatible constraints assigned to lines and power stations (option 3).

The target of the first two options was to analyze the influence of constraints of power transfers over lines and sections on the redistribution of loads among power stations and the change of the economic indicator of modes, that is the total sale price of sold power.

The target of the third option was to analyze the operation of GAMS under assigned incompatible constraints, what may take place rather often in case of a great number of controlled parameters.

Below we give calculation conditions for each option and the analysis of obtained results.

Because of practically the same mathematical problem statement in the developed GAMS model and the OPTIMUM complex operated in UDC, and also to have additional confirmation of the accuracy of results obtained through the GAMS model, we carried out comparing calculations for all three options both on the GAMS model and the OPTIMUM complex.

Option 1 (joint constraints)

Controlled Parameters	*Result (GAMS / OPTIMUM)*
Р1г (50 <= Р1г <= 200, Ц=325)	*200 / 200*

Р2г (**50 <=** Р2г <= **200, Ц=450)**	*50 / 50*
Р3г (**300 <=** Р3г <= 5**00, Ц=310)**	*398 / 400*
Р4г (**200 <=** Р4г <= **500, Ц=380)**	*252 / 250*
Рл1-2 (-100<=Рл1-2<=100)	*0 / 0*
Рл2-3 (-200<=Рл2-3<=200)	*-200 / -200*
Рл4-2 (-300<=Рл4-2<=300)	*252 / 250*
Рсеч1 (-300<=Рсеч1<=300)	*198 / 200*
F (objective function)	*98890.00*

Summary of the option results:

- All constraints are held;
- The most economical power station (3) is underloaded by 100 MW because of constraints on communication line 2-3;
- The most uneconomical power station (2) is unloaded to its minimum (50 MW);
- Practically complete coincidence of results on the GAMS model and the OPTIMUM complex

Option 2 (absence of constraints on transmission lines and sections)

Controlled Parameters	Result (GAMS / OPTIMUM)
Р1г (**50 <=** Р1г <= **200, Ц=325)**	150 / 150
Р2г (**50 <=** Р2г <= **200, Ц=450)**	50 / 50
Р3г (**300 <=** Р3г <= 5**00, Ц=310)**	500 / 500
Р4г (**200 <=** Р4г <= **500, Ц=380)**	200 / 200
Рл1-2	-48 / -50
Рл2-3	-302 / -300
Рл4-2	200 / 200
Рсеч1	-350 / -350
F (objective function)	94500.00

Summary of the option results:

- All constraints are held;
- Unlike the first option, the most economical power station 3 (500 MW) is completely loaded;
- Uneconomical power stations (2,4) are unloaded to their minimum (50 MW, 200 MW);
- Practically complete coincidence of results on the GAMS model and the OPTIMUM complex

Option 3 (incompatible constraints on line 2-3 and power station 3)

Controlled Parameters	Result (GAMS / OPTIMUM)
P1г (50 <= P1г <= 200, Ц=325)	200 / 200
P2г (50 <= P2г <= 200, Ц=450)	200 / 200
P3г (300 <= P3г <= 500, Ц=310)	300 / 250
P4г (200 <= P4г <= 500, Ц=380)	200 / 250
Рл1-2 (-100<=Рл1-2<=100)	2 / 0
Рл2-3 (-50<=Рл2-3<=100)	-102 / -50
Рл4-2 (-300<=Рл4-2<=300)	200 / 250
Рсеч1 (-300<=Рсеч1<=300)	-100 / -50
F (objective function)	116250.00

Summary of the option results:

- Solution on GAMS has a violated constraint (transfer over line 2-3 equals to 102 MW instead of assigned 50);
- On OPTIMUM we obtained the allowable mode through automated determination of the source of incompatibility (power station 3) and automated widening of available capacity range of power station 3 by the value of incompatibility;
- Sale price of power is considerably higher than that in options 1 and 2;
- Solution on GAMS requires additional analysis and at least refining of the optimization algorithm.

Refining Variant 1 of the Model

As we have already mentioned above, the analysis of the last result led to a refined optimization algorithm and additional variables included in the model to extend the regulation range of available capacity of power stations (Кг max, Кг min) and reduce consumption at nodes (Кпотр).
In addition, to simplify the algorithm in this model we adopted not generator's capacity increment within the Pg max - Pg min range accepted in the prior model variant, but full capacities of generators as independent variables on calculated power stations.

Below is given the GAMS model variant modified with regard to both factors.

```
Sets
 g  /g01*g04/                      # indices of calculated stations
 n  /n01*n03/                      #indices of consumption nodes
 ol /l01*l03/                      #line indices
 os /s01/                                 #section indices
 k / balans /                      #indices of power balances
     ;

Parameters                         #sale price of power

    c(g)
     /    g01  325
          g02  450
          g03  310
          g04  380
                /
  pgmin(g)                         #constrains in stations by  Pg min
     /    g01  50
          g02  50
          g03  300
          g04  200
                /
  pgmax(g)                         #constrains in stations by  Pg max
     /    g01  100
          g02  100
          g03  350
          g04  300
                /
 kpgmax(g)                         #ratio coefficients of accounting regulated range of  Pg
max
     /    g01  0.3
          g02  1
```

```
        g03  1
        g04  1
                /
kpgmin(g)                              # ratio coefficients of accounting regulated range of Pg min
   /   g01  1
        g02  1
        g03  1
        g04  1
                /
 ngr(n)                                         #consumption nodes
   /   n01  200
        n02  500
        n03  200
              /
krngr(n)                               #consumption ratio coefficients of accounting range
   /   n01  1
        n02  1
        n03  1
                /
ychngr(n)                      #amount of damage in the decrease of energy usage мvt/h in nodes
   /   n01  1
        n02  1
        n03  1
                /
 oglp(ol)                              #constrains in direct transfer lines
   /   l01   100
        l02   200
        l03   300
                /
  oglo(ol)                             #constrains in back power transfer lines
   /
        l01    100
        l02    50
        l03    300
                /
  ogsp(os)                             #constrains in directs power transfers of sections
   /
        s01    300
                /
  ogso(os)                             #constrains in back transfers of sections
   /
        s01     150

                /
  bal(k)                               #constrains in power balance
    /  balans    900  /
```

```
     ;

Table alg(g,ol)                          #distribution coefficients in lines for power stations
l01       l02    l03
     g01     0.7778    0.2222   0.0
     g02    -0.2222    0.2222   0.0
     g03    -0.2222   -0.7778   0.0
     g04    -0.2222    0.2222   1.0


 Table asg(g,os)                                  # distribution coefficients in sections for power
stations
          s01
     g01     1.0
     g02     0.0
     g03    -1.0
     g04     0.0

Table aln(n,ol)                          # distribution coefficients in lines for power consumers
l01       l02    l03
     n01     0.7778    0.2222   0.0
     n02    -0.2222    0.2222   0.0
     n03    -0.2222   -0.7778   0.0


 Table asn(n,os)                                  # distribution coefficients in sections for power
consumers
          s01
     n01     1.0
     n02     0.0
     n03    -1.0

Variables
      f,
    dpgmax,
    dpgmin,
    dpngr ;

  Positive Variables p(g),                        # .power of calculated stations
                      kgmax(g),          # increment of Pg max stations
                      kgmin(g),          # increment of Pg min stations
                      kngr(n),           # regulations on consumption
                      pkvl(ol),          # transfers on controlled lines
                      pksch(os)          # transfers on controlled sections
                       ;
```

```
Equations
      cel
      celpgmax
      celpgmin
      celngr
      ogrlp(ol)
      ogrlo(ol)
      ogrsp(os)
      ogrso(os)
      bales(k)  ;

                                   #objective functions
                                              # objective function of  UEP energy price
 cel ..        f      =e=  sum(g, c(g)*p(g))  ;

                                              # objective function of P max deviation
 celpgmax ..    dpgmax  =e=  sum(g, c(g)*kgmax(g)) ;

                                              # objective function of P min deviation
celpgmin ..    dpgmin  =e=  sum(g, c(g)*kgmin(g)) ;

                                              # objective function of P consumption deviation
celngr ..           dpngr   =e=  sum(n, ychngr(n)*kngr(n)) ;

                                              #constrains
 ogrlp(ol)  ..    sum(g,  alg(g,ol)  * (p(g)-kgmin(g)+kgmax(g)))
   +sum(n, aln(n,ol) * kngr(n)) =l=  oglp(ol) ;
 ogrlo(ol ) ..    sum(g, -alg(g,ol)  * (p(g)-kgmin(g)+kgmax(g)))
   +sum(n, -aln(n,ol) * kngr(n)) =l=  oglo(ol) ;
 ogrsp(os)  ..    sum(g,  asg(g,os)  * (p(g)-kgmin(g)+kgmax(g)))
   +sum(n, asn(n,os) * kngr(n)) =l=  ogsp(os) ;
 ogrso(os)  ..    sum(g, -asg(g,os)  * (p(g)-kgmin(g)+kgmax(g)))
   +sum(n, -asn(n,os) * kngr(n)) =l=  ogso(os) ;
 bales(k)   ..    sum(g, ( p(g)-kgmin(g)+kgmax(g) ))  =e=  bal(k) - sum(n,kngr(n)) ;

 p.UP(g) =  pgmax(g);
 p.lo(g) =  pgmin(g);
 kgmax.UP(g) = kpgmax(g) * pgmax(g);
 kgmin.UP(g) = kpgmin(g) * pgmin(g);
 kngr.UP(n) = krngr(n) * ngr(n);

Model opt /all/ ;

Solve opt using lp minimizing f ;
Solve opt using lp minimizing dpgmax ;
Solve opt using lp minimizing dpgmin ;
```

```
Solve opt using lp minimizing dpngr ;

  Display p.l ;

                                                    #calculation of power flows/transfers on lines

  LOOP(ol, pkvl.l(ol)  = sum(g, alg(g,ol) * (p.l(g)-kgmin.l(g)+kgmax.l(g)))
    +sum(n, aln(n,ol) * kngr.l(n))) ;
  LOOP(os, pksch.l(os) = sum(g, asg(g,os) * (p.l(g)-kgmin.l(g)+kgmax.l(g)))
    +sum(n, asn(n,os) * kngr.l(n))) ;

FILE OPTRPS /Odcres33.dat/
PUT OPTRPS;
                                                              #formation of the file of the results
PUT "------- PG: -------------"/;
PUT "PG1="; PUT p.l('g01'):8:2/
PUT "PG2="; PUT p.l('g02'):8:2/
PUT "PG3="; PUT p.l('g03'):8:2/
PUT "PG4="; PUT p.l('g04'):8:2/;
PUT /;

PUT "---- kgmax PG: ----------"/;
PUT "kgmax1="; PUT kgmax.l('g01'):8:2/
PUT "kgmax2="; PUT kgmax.l('g02'):8:2/
PUT "kgmax3="; PUT kgmax.l('g03'):8:2/
PUT "kgmax4="; PUT kgmax.l('g04'):8:2/;
PUT /;

PUT "---- kgmin PG: ----------"/;
PUT "kgmin1="; PUT kgmin.l('g01'):8:2/
PUT "kgmin2="; PUT kgmin.l('g02'):8:2/
PUT "kgmin3="; PUT kgmin.l('g03'):8:2/
PUT "kgmin4="; PUT kgmin.l('g04'):8:2/;
PUT /;

PUT "------- PGrez: ----------"/;
PUT "PG1="; PUT (p.l('g01')-kgmin.l('g01')+kgmax.l('g01')):7:2
PUT " PMAX="; PUT pgmax('g01'):7:2 PUT " PMIN="; PUT pgmin('g01'):7:2/
PUT "PG2="; PUT (p.l('g02')-kgmin.l('g02')+kgmax.l('g02')):7:2
PUT " PMAX="; PUT pgmax('g02'):7:2 PUT " PMIN="; PUT pgmin('g02'):7:2/
PUT "PG3="; PUT (p.l('g03')-kgmin.l('g03')+kgmax.l('g03')):7:2
PUT " PMAX="; PUT pgmax('g03'):7:2 PUT " PMIN="; PUT pgmin('g03'):7:2/
PUT "PG4="; PUT (p.l('g04')-kgmin.l('g04')+kgmax.l('g04')):7:2
PUT " PMAX="; PUT pgmax('g04'):7:2 PUT " PMIN="; PUT pgmin('g04'):7:2/
PUT /;
```

```
PUT "-------- kngr: ----------"/;
PUT "kngr1="; PUT kngr.l('n01'):8:2/
PUT "kngr2="; PUT kngr.l('n02'):8:2/
PUT "kngr3="; PUT kngr.l('n03'):8:2/
PUT /;

PUT "------- Pnagrrez: ----------"/;
PUT "Pn1="; PUT (ngr('n01') - kngr.l('n01')):8:2 PUT " Pnisx="; PUT ngr("n01"):8:2/
PUT "Pn2="; PUT (ngr('n02') - kngr.l('n02')):8:2 PUT " Pnisx="; PUT ngr("n02"):8:2/
PUT "Pn3="; PUT (ngr('n03') - kngr.l('n03')):8:2 PUT " Pnisx="; PUT ngr("n03"):8:2/
PUT /;

PUT "---------- PL:--------------"/;
PUT "PL1="; PUT pkvl.l('l01'):7:2 PUT " PP="; PUT oglp('l01'):7:2
PUT " PO="; PUT oglo('l01'):7:2/
PUT "PL2="; PUT pkvl.l('l02'):7:2 PUT " PP="; PUT oglp('l02'):7:2
PUT " PO="; PUT oglo('l02'):7:2/
PUT "PL3="; PUT pkvl.l('l03'):7:2 PUT " PP="; PUT oglp('l03'):7:2
PUT " PO="; PUT oglo('l03'):7:2/
PUT /;

PUT "---------- SECH-------------"/;
PUT "PS1="; PUT pksch.l('s01'):7:2 PUT " PP="; PUT ogsp('s01'):7:2
PUT " PO="; PUT ogso('s01'):7:2/
PUT /;

PUT "---------- CEL:--------------"/;
PUT "CEL="; PUT f.l:9:2/;
PUT "CELPGMAX="; PUT dpgmax.l:9:2/;
PUT "CELPGMIN="; PUT dpgmin.l:9:2/;
PUT "CELNGR=";   PUT dpngr.l:9:2/;
PUTCLOSE OPTRPS;
```

We tested the modified model on the same simplest circuit. By changing mode data in the circuit, we modeled the conditions requiring simultaneous use of all three additional variables for the mode to enter an admissible range (Figure 2).

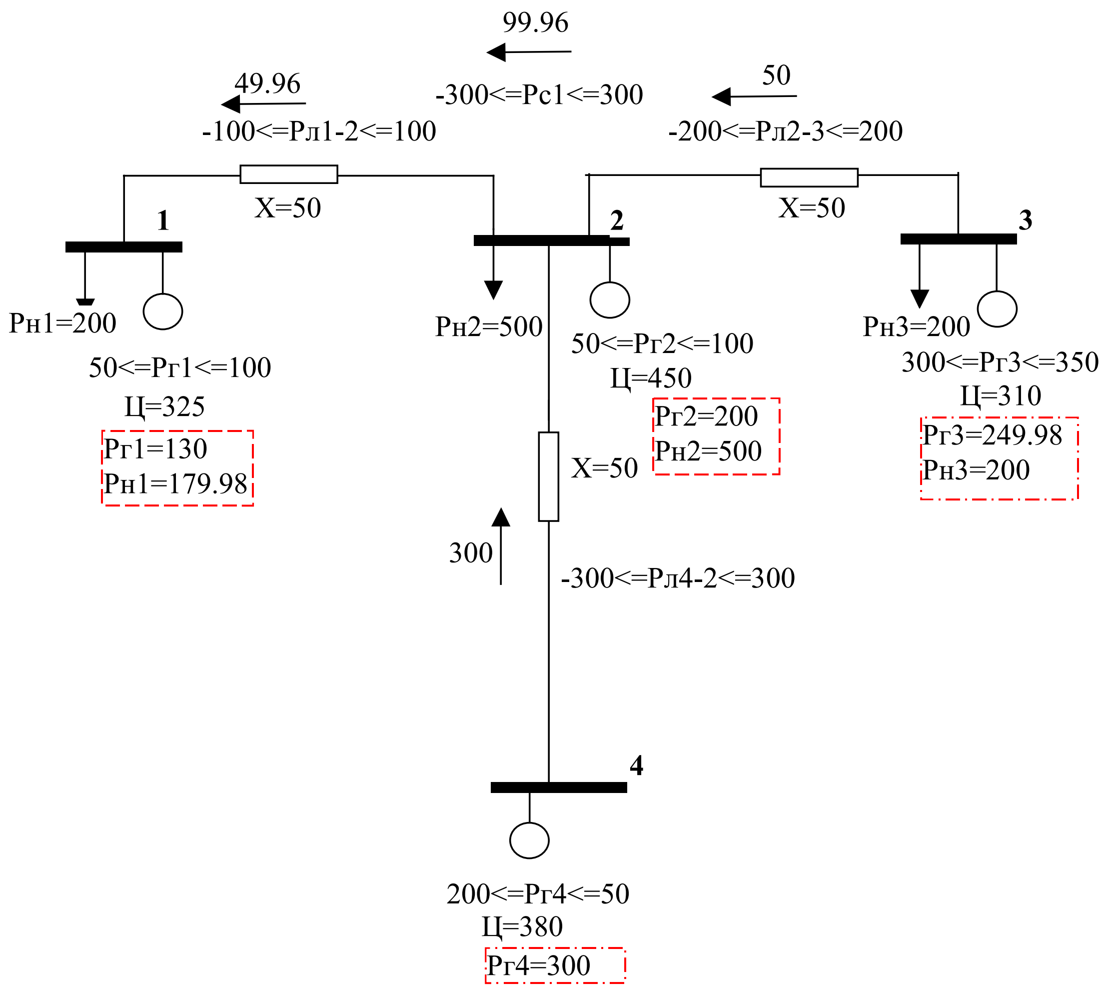

Figure 2. Design Circuit.

Thus, in node 3 to hold constraints on transfers of 50 MW along lines 2 - 3, it is necessary to decrease Pg min. of the station in node 3 by 50 MW and make it equal to 250 MW. Because of the total initial deficit of the generating power of 50 MW (sum of Pg=850MW, sum of P consum. = 900 MW) and blocking conditions of 100MW of the generating power in node 3 (because of constrains in lines 2 – 3 in the scheme there is a deficit of the generating power of 150 MW). This deficit may be filled through the increased P max. of stations 2, 3 and/or decreased consumption in nodes 1, 2 and 4.

The results of the conducted calculation are drawn on the circuit (Figure 2) and are given in the following table in a generalized form.

Parameters/Nodes	1	2	3	4
Pgen мin \ Kgen min	50 \ 1.0	50 \ 1.0	300 \ 1.0	200 \ 1.0
Pgen max \ Kgen max	100 \ 0.3	100 \ 1.0	350 \ 1.0	300 \ 1.0
Pgen	100	100	300	300
Deviation of Pgen min			50.02	
Deviation of Pgen max	30	100		
Pgen of a station	130	200	249.98	300
P usage \ Кнагр	200 \ 1.0	500 \ 1.0	200 \ 1.0	
Deviation of P usage	20.02			
P usage resulting	179.98	500	200	
P of a node	49.98	300	-49.98	-300

As you can see on the circuit and the table of calculation results, everything went as we expected. Indeed, station 3 is unloaded to the minimum by 50 MW. Stations 1,2 and 4 are loaded to the maximum with regard to a possible P max. increase. At stations 1 and 2, the P max. is increased relatively by 30 and 100 MW. (K gen. max1* P max. 1=0.3*100 = 30, Kgen. max2 * Pmax2 = 1.0 * 100 = 100). Despite the power deficit (20MW) no increase of P max was traced at station 4, though the regulating range at the station was 300 MW (Kgen max4 * Pmax4 = 1.0 *300 = 300). The reason of this is the absence of a possibility to generate additional power because of constrains on lines 2 – 4. Decreased consumption in node 1 covered the power deficit of 20 MW.

To confirm the specified results below we give a printout of the calculation result file formed by the model.

```
------- PG: -------------
PG1=  100.00
PG2=  100.00
PG3=  300.00
PG4=  300.00

---- kgmax PG: ----------
kgmax1=   30.00
kgmax2=  100.00
kgmax3=    0.00
kgmax4=    0.00

---- kgmin PG: ----------
kgmin1=    0.00
kgmin2=    0.00
kgmin3=   50.02
```

kgmin4=   0.00

------- PGrez: ----------
PG1= 130.00 PMAX= 100.00 PMIN= 50.00
PG2= 200.00 PMAX= 100.00 PMIN= 50.00
PG3= 249.98 PMAX= 350.00 PMIN= 300.00
PG4= 300.00 PMAX= 300.00 PMIN= 200.00

-------- kngr: ----------
kngr1=   20.02
kngr2=   0.00
kngr3=   0.00

------- Pnagrrez: ----------
Pn1= 179.98 Pnisx= 200.00
Pn2= 500.00 Pnisx= 500.00
Pn3= 200.00 Pnisx= 200.00
---------- PL:--------------
PL1= -49.96 PP= 100.00 PO= 100.00
PL2= -50.00 PP= 200.00 PO= 50.00
PL3= 300.00 PP= 300.00 PO= 300.00

---------- SECH-------------
PS1= -99.96 PP= 300.00 PO= 150.00

---------- CEL:--------------
CEL=284500.00
CELPGMAX= 54750.00
CELPGMIN= 15506.20
CELNGR=   20.02

In order to be convinced that additional independent deviation variables Pmax, Pmin, Pconsum. introduced into the algorithm are used only in case of necessity, we conducted calculation on the same circuit under the conditions of almost absolute absence of any constrains. Calculation conditions and the obtained results are given below on the circuit (Figure 3) and in the table.

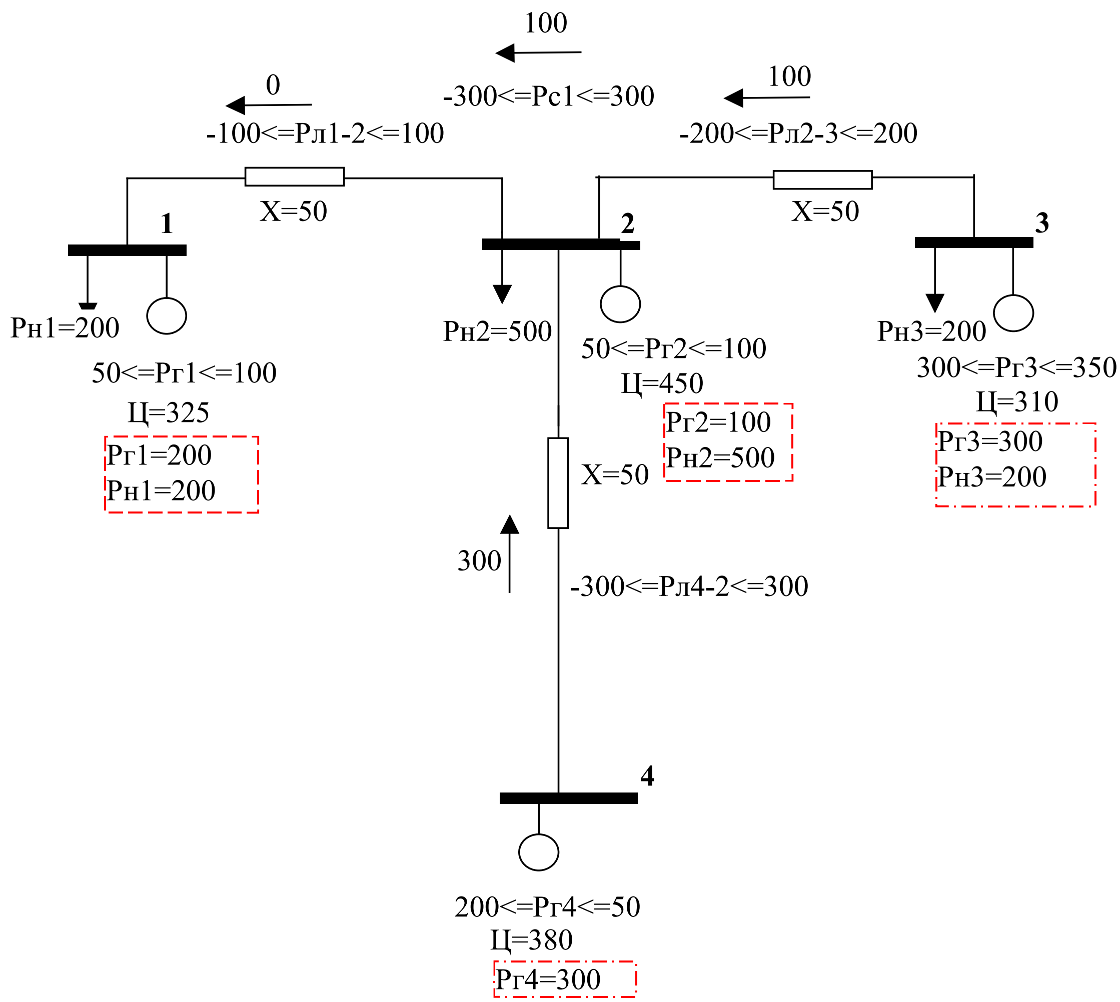

Figure 3. Design Circuit

Calculation Results

Parameters/Nodes	**1**	**2**	**3**	**4**
Pgen min \ Kgen min	50 \ 1.0	50 \ 1.0	300 \ 1.0	200 \ 1.0
Pgen max \ Kgen max	200 \ 1.0.	200 \ 1.0	500 \ 1.0	500 \ 1.0
Pgen	200	200	300	300
Deviation of Pgen min				
Deviation of Pgen max				
Pgen of a station	200	200	300	300
P usage \ Kusage	200 \ 1.0	500 \ 1.0	200 \ 1.0	
Deviation P usage				

P usage resulting	200	500	200	
P of a node	0	300	-100	-300

As you can see on the circuit and the table, calculation results confirms this completely. To confirm the specified results below we give a printout of the calculation result file formed by the model.

```
------- PG: -------------
PG1=  200.00
PG2=  100.00
PG3=  300.00
PG4=  300.00

---- kgmax PG: ----------
kgmax1=    0.00
kgmax2=    0.00
kgmax3=    0.00
kgmax4=    0.00

---- kgmin PG: ----------
kgmin1=    0.00
kgmin2=    0.00
kgmin3=    0.00
kgmin4=    0.00

------- PGrez: ----------
PG1= 200.00 PMAX= 200.00 PMIN=  50.00
PG2= 100.00 PMAX= 200.00 PMIN=  50.00
PG3= 300.00 PMAX= 500.00 PMIN= 300.00
PG4= 300.00 PMAX= 500.00 PMIN= 200.00

-------- kngr: ----------
kngr1=    0.00
kngr2=    0.00
kngr3=    0.00

------- Pnagrrez: ----------
Pn1=  200.00 Pnisx=  200.00
Pn2=  500.00 Pnisx=  500.00
Pn3=  200.00 Pnisx=  200.00

---------- PL:--------------
PL1=   0.02 PP= 100.00 PO= 100.00
PL2=-100.02 PP= 200.00 PO= 200.00
PL3= 300.00 PP= 300.00 PO= 300.00
```

---------- SECH-------------
PS1=-100.00 PP= 300.00 PO= 150.00

---------- CEL:--------------
CEL=317000.00
CELPGMAX=   0.00
CELPGMIN=   0.00
CELNGR=   0.00

We tested this model variant within the OPTIMUM complex. For this purpose, we developed interface modules to incorporate the GAMS model in the complex. We tested the variant within the complex both on the given controlled example and real circuit and actual data.

The calculation results coincided completely.

We based the real EPP CA circuit calculation on the data for December 8, 1999. The elements and features of the EPP CA circuit, which served the basis for the calculation, are given in the OPTIMUM complex user's guide attached to the report. In the interim progress report, we provided the calculation results we obtained.
The calculation results confirmed the possibility to use GAMS to optimize the actual modes of the EPP CA.

In particular, regarding the given calculation

- For all 24 hours we obtained the modes allowable in terms of holding the entire set of assigned constraints;
- For incompatible constraints, we conducted calculation minimizing possible deviations from assigned parameters.

Thus, for the 17th hour we assigned the deficit of generating capacity in the EPP CA. We could solve the problem within the model in two ways: either we increase maximum available capacities of power stations, or we decrease power consumption in nodes. By selecting coefficients for the objective function, we chose the second way. Consequently, we decreased capacity in node 3 (substation Kuilyuk) by 109 MW, what was fixed in the calculation protocol on the screen and in output documents of the complex.

Developing and Testing Variant 2 of the Model

Based on the first modified variant, we built the second variant of the model of the operational planning complex. According to the TOR the 2-nd variant of the optimization of a complex of operative planning model should be constructed on the basis of 1-st variant of the model and should include the following additional conditions and constraints:

- Simultaneous calculation within the framework of the model for all 24 hours of the planned day;

- Consideration of integrated daily constraints:
    - On balance transfers of active power of power systems;
    - On generation of electric power or consumption of energy carriers (water / fuel) at the stations under control.

Realization of these additional functions was carried out on the basis of the 1-st variant of the GAMS model by means of entering into it the following changes and amendments:

- The following additional sets and sub sets are introduced into the model:
    - Structure of energy systems controlled on balance transfers (PS);
    - Settlement hours (tm);
    - Structure of settlement stations controlled on the daily generation/production (vir);
    - Structure of settlement stations controlled on the daily consumption of energy carriers (rasx);
    - The specific and daily consumption of energy carriers at stations (prasx);
    - Fitting/Accessory of settlement stations and loadings to PS (pres);
    - Accuracy on performance of constraints (toch).

- the following parameters are additionally included and changed in the model:
    - additionally included:
        - fixed loadings of PS (fnges);
        - fixed values of balance transfers controlled by PS (zdsaldes);
        - fixed values of performance accuracy of constraints (zdtoch);
        - fixed values of daily generation of stations (zdvirst);
        - specific consumptions of energy carriers at stations (urasx);
        - values fixed for a day of energy carriers consumptions at stations (zdrasx);
        - Settlement values of balance transfers of PS for one day (saldes _ rez);
        - Settlement values of the consumptions of energy carriers at stations for one day (rasx _ rez).
    - by inclusion of settlement hours index(tm), the following parameters are transformed into two-dimentional tables:
        - Release prices of the electric power of settlement stations (c);
        - Constraints on capacity of stations (pgmin, pgmax);
        - Factors of an additional adjusting range of stations' capacity (kpgmin, kpgmax);
        - Loadings of units (ngr);
        - Factors of an adjusting range of loadings (krng);
        - damage prices from short delivery of the electric power in loading units (ychngr);
        - Constraints of power transfers on lines and sections (oglp, oglo, ogsp, ogso);
        - Balance of capacity on UDC (bal).
    - By including an additional index of settlement hours (tm) factors of distribution of capacity of stations, and also loadings on lines and sections of lines are transformed into three dimentioanal tables (alg, asg, aln, asn);
    - By inclusion of an index of settlement hours (tm) all positive variables are transformed into tow-dimentional files/blocks;
    - Inclusion of an index of settlement hours (tm) transforms criterion function, constraint equations of on power transfers of lines and sections of lines, on power balance, on

capacities and increment of power stations, on deviations of loadings in units, and also expressions for calculation of power transfers on lines and sections of lines;

- additional equations on constraints of daily values of balance transfers of PS (saldes (es)), development and consumption of energy flows at stations (virst (g), eqrasx (g)) are included;

• expressions to calculate resulting daily values of power generation and energy carrier consumption by stations (rvirst, rasx _ rez), balance transfers of PS (saldes _ rez) are added;
• operators of record of the resulting data into a file of results are transformed.

Below we give the final text of the GAMS model variant 2 as applied to the data of the simplest test circuit.

```
*** ---------------------------------
*** scheme 1, model 2, variant 3
*** - raschet 24-x chasov
*** - objedin.cel.funk i odin solver
*** - ogranich.saldo energosystem za sutkki (unificirovannoe uravnenie)
*** - ogranich.po virabotke stanciy za sutkki
*** - ogranich.po rasxodu vodi ili topliva na stanciy za sutkki
*** -
*** -
*** Rojnov E.P. (UDC "Energia")
*** 10.02.2000
*** ------------------------------------- --------------------
$ Eolcom .)

Sets

 Gn /g01*g04, n01*n03/         .) Mnoj-vo stancii i nagruzok
 G (gn) /g01*g04/        .) Mnoj-vo stancii
 N (gn) /n01*n03/        .) Mnoj-vo nagruzki
 Ol /l01*l03/    .) Linii
 Es /es01*es02/ .) energosystem
 Os /s01/          .) Sechenij
 Tm /01*24/     .) Chasi
 K /bls/                       .) Balans mochnosti
 Vir (g) /g01/ .) stancii s zadannoi virabotkoi za sutki
 Rasx (g) /g02, g03/ .) stancii s zad.rasxodom vodi\topliva za sutki
 Prasx /urasx, srasx/ .) udeljnyi i sutochniy rasxod stancii
 Toch /ts, tw, tr/ .) tochnosti v % (ts-saldo, tw-virab.tr-rasxod)

 Pres (es, gn)                          .) Prinadlej.stancii\nagruzok k energosystemam
 / Es01.g01, es01.g02, es01.n01, es01.n02,
   Es02.g03, es02.g04, es02.n03
             /;
```

```
Parameters

 Fnges (es) .) fiksir.nagr.es (sum (nagr + neras + fikc.stan + vnesh))
   /'es01 ' 16800 / .) 16800 = (200 + 500) *24

 Zdtoch (toch)            .) Tochn.ogranich.po saldo es, virabotk.rasxodu stanciy
   /'ts' 1
    'Tw' 1
    'Tr' 1 /

Zdsaldes (es) .) zadannie.saldoperetoki energosystem za sutki
   /'es01 ' 8400 / .) 8400 = 350*24


Zdvirst (g) .) zadannie.virabotki stanciy za sutki
   /'g01 ' 2400 /            .) 100*24 = 2400

Urasx (g)                 .) Zadannie.udeljniy rasxod stanciy
   /'g02 ' 2 /

Zdrasx (g)                .) Zadannie rasxod stanciy za sutki
   /'g02 ' 9600 /

Saldes _ rez (es)                  .) Raschetnoe saldo PS za sutki

Rasx _ rez (g)            .) Raschetnoe rasxod stanciy za sutki

*** Otpusknaj cena energii stanciy
Table c (g, tm)
       01 02 03 04 05 06 07 08 09 10 11 12
   G01 325 325 325 325 325 325 325 325 325 325 325 325
   G02 450 450 450 450 450 450 450 450 450 450 450 450
   G03 310 310 310 310 310 310 310 310 310 310 310 310
   G04 380 380 380 380 380 380 380 380 380 380 380 380
   +
       13 14 15 16 17 18 19 20 21 22 23 24
   G01 325 325 325 325 325 325 325 325 325 325 325 325
   G02 450 450 450 450 450 450 450 450 450 450 450 450
   G03 310 310 310 310 310 310 310 310 310 310 310 310
   G04 380 380 380 380 380 380 380 380 380 380 380 380

*** Pgmin stanciy
Table pgmin (g, tm)
       01 02 03 04 05 06 07 08 09 10 11 12
   G01 50 50 50 50 50 50 50 50 50 50 50 50
```

```
  G02 50 50 50 50 50 50 50 50 50 50 50 50
  G03 300 300 300 300 300 300 300 300 300 300 300 300
  G04 200 200 200 200 200 200 200 200 200 200 200 200
  +
      13 14 15 16 17 18 19 20 21 22 23 24
  G01 50 50 50 50 50 50 50 50 50 50 50 50
  G02 50 50 50 50 50 50 50 50 50 50 50 50
  G03 300 300 300 300 300 300 300 300 300 300 300 300
  G04 200 200 200 200 200 200 200 200 200 200 200 200

*** Pgmax stanciy
Table pgmax (g, tm)
      01 02 03 04 05 06 07 08 09 10 11 12
  G01 100 100 100 100 100 100 100 100 100 100 100 100
  G02 100 100 100 100 100 100 100 100 100 100 100 100
  G03 350 350 350 350 350 350 350 350 350 350 350 350
  G04 300 300 300 300 300 300 300 300 300 300 300 300
  +
      13 14 15 16 17 18 19 20 21 22 23 24
  G01 100 100 100 100 100 100 100 100 100 100 100 100
  G02 100 100 100 100 100 100 100 100 100 100 100 100
  G03 350 350 350 350 350 350 350 350 350 350 350 350
  G04 300 300 300 300 300 300 300 300 300 300 300 300

*** Koef-t regul.pgmax stanciy
Table kpgmax (g, tm)
      01 02 03 04 05 06 07 08 09 10 11 12
  G01 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
  G02 1 1 1 1 1 1 1 1 1 1 1 1
  G03 1 1 1 1 1 1 1 1 1 1 1 1
  G04 1 1 1 1 1 1 1 1 1 1 1 1
  +
      13 14 15 16 17 18 19 20 21 22 23 24
  G01 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
  G02 1 1 1 1 1 1 1 1 1 1 1 1
  G03 1 1 1 1 1 1 1 1 1 1 1 1
  G04 1 1 1 1 1 1 1 1 1 1 1 1

*** Koef-t regul.pgmin stanciy
Table kpgmin (g, tm)
      01 02 03 04 05 06 07 08 09 10 11 12
  G01 1 1 1 1 1 1 1 1 1 1 1 1
  G02 1 1 1 1 1 1 1 1 1 1 1 1
  G03 1 1 1 1 1 1 1 1 1 1 1 1
  G04 1 1 1 1 1 1 1 1 1 1 1 1
  +
```

```
       13 14 15 16 17 18 19 20 21 22 23 24
  G01 1 1 1 1 1 1 1 1 1 1 1 1
  G02 1 1 1 1 1 1 1 1 1 1 1 1
  G03 1 1 1 1 1 1 1 1 1 1 1 1
  G04 1 1 1 1 1 1 1 1 1 1 1 1

*** Nagruzka uzlov
Table ngr (n, tm)
       01 02 03 04 05 06 07 08 09 10 11 12
  N01 200 200 200 200 200 200 200 200 200 200 200 200
  N02 500 500 500 500 500 500 500 500 500 500 500 500
  N03 200 200 200 200 200 200 200 200 200 200 200 200
  +
       13 14 15 16 17 18 19 20 21 22 23 24
  N01 200 200 200 200 200 200 200 200 200 200 200 200
  N02 500 500 500 500 500 500 500 500 500 500 500 500
  N03 200 200 200 200 200 200 200 200 200 200 200 200

*** Koef-t regul.nagruzki
Table krngr (n, tm)
       01 02 03 04 05 06 07 08 09 10 11 12
  N01 1 1 1 1 1 1 1 1 1 1 1 1
  N02 1 1 1 1 1 1 1 1 1 1 1 1
  N03 1 1 1 1 1 1 1 1 1 1 1 1
  +
       13 14 15 16 17 18 19 20 21 22 23 24
  N01 1 1 1 1 1 1 1 1 1 1 1 1
  N02 1 1 1 1 1 1 1 1 1 1 1 1
  N03 1 1 1 1 1 1 1 1 1 1 1 1

*** Cena ucherba nagruzri
Table ychngr (n, tm)
       01 02 03 04 05 06 07 08 09 10 11 12
  N01 500 500 500 500 500 500 500 500 500 500 500 500
  N02 500 500 500 500 500 500 500 500 500 500 500 500
  N03 500 500 500 500 500 500 500 500 500 500 500 500
  +
       13 14 15 16 17 18 19 20 21 22 23 24
  N01 500 500 500 500 500 500 500 500 500 500 500 500
  N02 500 500 500 500 500 500 500 500 500 500 500 500
  N03 500 500 500 500 500 500 500 500 500 500 500 500

*** Ogranichenij peretokov po linijm (prjmoi)
Table oglp (ol, tm)
       01 02 03 04 05 06 07 08 09 10 11 12
  L01 100 100 100 100 100 100 100 100 100 100 100 100
```

```
   L02 200 200 200 200 200 200 200 200 200 200 200 200
   L03 300 300 300 300 300 300 300 300 300 300 300 300
   +
        13 14 15 16 17 18 19 20 21 22 23 24
   L01 100 100 100 100 100 100 100 100 100 100 100 100
   L02 200 200 200 200 200 200 200 200 200 200 200 200
   L03 300 300 300 300 300 300 300 300 300 300 300 300

*** Ogranichenij peretokov po linijm (obratniy)
Table oglo (ol, tm)
        01 02 03 04 05 06 07 08 09 10 11 12
   L01 100 100 100 100 100 100 100 100 100 100 100 100
   L02 50 50 50 50 50 50 50 50 50 50 50 50
   L03 300 300 300 300 300 300 300 300 300 300 300 300
   +
        13 14 15 16 17 18 19 20 21 22 23 24
   L01 100 100 100 100 100 100 100 100 100 100 100 100
   L02 50 50 50 50 50 50 50 50 50 50 50 50
   L03 300 300 300 300 300 300 300 300 300 300 300 300


*** Ogranichenij peretokov po sechenijm (prjmoi)
Table ogsp (os, tm)
        01 02 03 04 05 06 07 08 09 10 11 12
   S01 300 300 300 300 300 300 300 300 300 300 300 300
   +
        13 14 15 16 17 18 19 20 21 22 23 24
   S01 300 300 300 300 300 300 300 300 300 300 300 300

*** Ogranichenij peretokov po sechenijm (obratniy)
Table ogso (os, tm)
        01 02 03 04 05 06 07 08 09 10 11 12
   S01 150 150 150 150 150 150 150 150 150 150 150 150
   +
        13 14 15 16 17 18 19 20 21 22 23 24
   S01 150 150 150 150 150 150 150 150 150 150 150 150

*** Balans mochnosti po oes
Table bal (k, tm)
        01 02 03 04 05 06 07 08 09 10 11 12
   Bls 900 900 900 900 900 900 900 900 900 900 900 900
   +
        13 14 15 16 17 18 19 20 21 22 23 24
   Bls 900 900 900 900 900 900 900 900 900 900 900 900

*** Koef-ti raspredelenij liniy po ctancijm
```

```
Table alg (g, ol, tm)
     L01.01 l01.02 l01.03 l01.04 l01.05 l01.06 l01.07 l01.08
  G01 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778
  G02 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  G03 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  G04 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  +
     L01.09 l01.10 l01.11 l01.12 l01.13 l01.14 l01.15 l01.16
  G01 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778
  G02 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  G03 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  G04 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  +
     L01.17 l01.18 l01.19 l01.20 l01.21 l01.22 l01.23 l01.24
  G01 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778
  G02 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  G03 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  G04 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
  +
     L02.01 l02.02 l02.03 l02.04 l02.05 l02.06 l02.07 l02.08
  G01 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  G02 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  G03 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778
  G04 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  +
     L02.09 l02.10 l02.11 l02.12 l02.13 l02.14 l02.15 l02.16
  G01 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  G02 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  G03 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778
  G04 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  +
     L02.17 l02.18 l02.19 l02.20 l02.21 l02.22 l02.23 l02.24
  G01 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  G02 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  G03 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778
  G04 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
  +
     L03.01 l03.02 l03.03 l03.04 l03.05 l03.06 l03.07 l03.08
  G01 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
  G02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
  G03 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
  G04 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
  +
     L03.09 l03.10 l03.11 l03.12 l03.13 l03.14 l03.15 l03.16
  G01 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
  G02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

G03 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
G04 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
+
L03.17 l03.18 l03.19 l03.20 l03.21 l03.22 l03.23 l03.24
G01 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
G02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
G03 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
G04 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0

*** Koef-ti raspredelenij secheniy po ctancijm
Table asg (g, os, tm)
S01.01 s01.02 s01.03 s01.04 s01.05 s01.06 s01.07 s01.08
G01 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
G02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
G03 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0
G04 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
+
S01.09 s01.10 s01.11 s01.12 s01.13 s01.14 s01.15 s01.16
G01 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
G02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
G03 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0
G04 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
+
S01.17 s01.18 s01.19 s01.20 s01.21 s01.22 s01.23 s01.24
G01 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
G02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
G03 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0
G04 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

*** Koef-ti raspredelenij liniy po nagruzkam
Table aln (n, ol, tm)
L01.01 l01.02 l01.03 l01.04 l01.05 l01.06 l01.07 l01.08
N01 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778
N02 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
N03 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
+
L01.09 l01.10 l01.11 l01.12 l01.13 l01.14 l01.15 l01.16
N01 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778
N02 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
N03 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
+
L01.17 l01.18 l01.19 l01.20 l01.21 l01.22 l01.23 l01.24
N01 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778 0.7778
N02 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222

```
 N03 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222 -0.2222
 +
     L02.01 l02.02 l02.03 l02.04 l02.05 l02.06 l02.07 l02.08
 N01 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
 N02 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
 N03 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778
 +
     L02.09 l02.10 l02.11 l02.12 l02.13 l02.14 l02.15 l02.16
 N01 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
 N02 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
 N03 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778
 +
     L02.17 l02.18 l02.19 l02.20 l02.21 l02.22 l02.23 l02.24
 N01 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
 N02 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222 0.2222
 N03 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778 -0.7778
 +
     L03.01 l03.02 l03.03 l03.04 l03.05 l03.06 l03.07 l03.08
 N01 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N03 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 +
     L03.09 l03.10 l03.11 l03.12 l03.13 l03.14 l03.15 l03.16
 N01 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N03 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 +
     L03.17 l03.18 l03.19 l03.20 l03.21 l03.22 l03.23 l03.24
 N01 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N03 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

Table asn (n, os, tm)
     S01.01 s01.02 s01.03 s01.04 s01.05 s01.06 s01.07 s01.08
 N01 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 N02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N03 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0
 +
     S01.09 s01.10 s01.11 s01.12 s01.13 s01.14 s01.15 s01.16
 N01 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 N02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 N03 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0
 +
     S01.17 s01.18 s01.19 s01.20 s01.21 s01.22 s01.23 s01.24
 N01 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 N02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

```
 N03 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0

Variables
     F; .) sum otpusknaj stoimostj energii OPS za sutki

 Positive Variables
     P (g, tm), .) nagruzka raschetnix stancij OPS po chasam
     Kgmax (g, tm), .) nabros pgmax raschetnix stancij OPS po chasam
     Kgmin (g, tm), .) cnijenie pgmin raschetnix stancij OPS po chasam
     Kngr (n, tm), .) cnijenie nagruzki uzlov OPS po chasam
     Pkvl (ol, tm), .) peretoki po linijm po chasam
     Pksch (os, tm) .) peretoki po sechenijm po chasam
     Rvirst (g) .) virabotka stanci za sutki
              ;

 Equations
     Cel (tm) .) sum otpusknaj stoimostj energii OPS za sutki
     Ogrlp (ol, tm) .) ogranichenij prjmix peretokov linij po chasam
     Ogrlo (ol, tm) .) ogranichenij obratnix peretokov linij po chasam
     Ogrsp (os, tm) .) ogranichenij prjmix peretokov sechenii po chasam
     Ogrso (os, tm) .) ogranichenij obratnix peretokov sechenii po chasam
     Bales (k, tm) .) balans mochnosti OPS po chasam
     Saldes (es) .) saljdo peretoki po energosystemam
     Virst (g) .) virabotka stanciy za sutki
     Eqrasx (g) .) rasxod stanciy za sutki
          ;

***                        C e l e v a j f u n k c i j

 Cel (tm).. F = e = sum (g, c (g, tm) *p (g, tm))
                          + Sum (g, c (g, tm) *kgmax (g, tm))
                          + Sum (g, c (g, tm) *kgmin (g, tm))
                          + Sum (n, ychngr (n, tm) *kngr (n, tm));

***                        O g r a n i c h e n i j

***                                 Peretoki po linijm
 Ogrlp (ol, tm).. Sum (g, alg (g, ol, tm) * (p (g, tm) -kgmin (g, tm) + kgmax (g, tm)))
    + Sum (n, aln (n, ol, tm) * kngr (n, tm)) = l = oglp (ol, tm);
 Ogrlo (ol, tm).. Sum (g, -alg (g, ol, tm) * (p (g, tm) -kgmin (g, tm) + kgmax (g, tm)))
    + Sum (n, -aln (n, ol, tm) * kngr (n, tm)) = l = oglo (ol, tm);

***                                 Peretoki po sechenijm linii
 Ogrsp (os, tm).. Sum (g, asg (g, os, tm) * (p (g, tm) -kgmin (g, tm) + kgmax (g, tm)))
    + Sum (n, asn (n, os, tm) * kngr (n, tm)) = l = ogsp (os, tm);
 Ogrso (os, tm).. Sum (g, -asg (g, os, tm) * (p (g, tm) -kgmin (g, tm) + kgmax (g, tm)))
```

```
    + Sum (n, -asn (n, os, tm) * kngr (n, tm)) = l = ogso (os, tm);

***                             Balans mochnosti
  Bales (k, tm).. Sum (g), p (g, tm) -kgmin (g, tm) + kgmax (g, tm))) = e = bal (k, tm)
    - Sum (n, kngr (n, tm));

***                             Saljdoperetoki energosystem
Saldes (es) $ zdsaldes (es).. Fnges (es) - sum (g $ (pres (es, g)), sum (tm), p (g, tm) - kgmin (g,
    tm) + kgmax (g, tm)))) -sum (n $ (pres (es, n)), sum (tm, kngr (n, tm)))
   - Zdsaldes (es) = l = (zdtoch (' ts) * zdsaldes (es)) /100;

***                             Virabotka ctanciy za sutki
  Virst (g) $ vir (g).. Sum (tm), p (g, tm) -kgmin (g, tm) + kgmax (g, tm))) - zdvirst (g)
                   = l = (zdtoch (' tw ') * zdvirst (g)) /100;

***                             Rasxod ctanciy za sutki
  Eqrasx (g) $ zdrasx (g).. Sum (tm), p (g, tm) -kgmin (g, tm) + kgmax (g, tm))) * urasx (g)
      - Zdrasx (g) = l = (zdtoch (' tr ') * zdrasx (g)) /100;

***                             Mochnosti stancii
  p. UP (g, tm) = pgmax (g, tm);
  P.lo (g, tm) = pgmin (g, tm);

***                             Prirachenij mochnosti stancii i nagruzki
  Kgmax. UP (g, tm) = kpgmax (g, tm) * pgmax (g, tm);
  Kgmin. UP (g, tm) = kpgmin (g, tm) * pgmin (g, tm);
  Kngr. UP (n, tm) = krngr (n, tm) * ngr (n, tm);

Model opt /all/;

  Solve opt using lp minimizing f;

*** Display p.l;

***                             Vichislenie peretokov po linijm
  LOOP (ol, pkvl.l (ol, tm) = sum (g, alg (g, ol, tm) * (p.l (g, tm) -kgmin.l (g, tm)
    + Kgmax.l (g, tm))) + sum (n, aln (n, ol, tm) * kngr.l (n, tm)));

***                             Vichislenie peretokov po secheniym
  LOOP (os, pksch.l (os, tm) = sum (g, asg (g, os, tm) * (p.l (g, tm) -kgmin.l (g, tm)
    + Kgmax.l (g, tm))) + sum (n, asn (n, os, tm) * kngr.l (n, tm)));

***                             Vichislenie virabotki stanciy
  LOOP (g, rvirst.l (g) = sum (tm, (p.l (g, tm) -kgmin.l (g, tm) + kgmax.l (g, tm))));

***                             Vichislenie saldoperetokov PS
```

```
Saldes _ rez (es) = fnges (es) - sum (g $ (pres (es, g)), sum (tm), p.l (g, tm) -kgmin.l (g, tm) +
    kgmax.l (g, tm)))) -sum (n $ pres (es, n), sum (tm, kngr.l (n, tm)));

***                              Vichislenie rasxodov vodi ili topliva stancii
 Rasx _ rez (g) = sum (tm), p.l (g, tm) -kgmin.l (g, tm) + kgmax.l (g, tm))) * urasx (g);


FILE OPTRPS /Odcres53.dat/
PUT OPTRPS;

PUT " --------- clock = 05 --------- " /;
PUT " ------- delta PG: ----------- " /;
PUT " PG1 = "; PUT p.l ('g01', '05'):8:2/
PUT " PG2 = "; PUT p.l ('g02', '05'):8:2/
PUT " PG3 = "; PUT p.l ('g03', '05'):8:2/
PUT " PG4 = "; PUT p.l ('g04', '05'):8:2 /;
PUT /;

PUT " ------- kgmax PG: ---------- " /;
PUT " kgmax1 = "; PUT kgmax.l ('g01', '05'):8:2/
PUT " kgmax2 = "; PUT kgmax.l ('g02', '05'):8:2/
PUT " kgmax3 = "; PUT kgmax.l ('g03', '05'):8:2/
PUT " kgmax4 = "; PUT kgmax.l ('g04', '05'):8:2 /;
PUT /;

PUT " ------- kgmin PG: ---------- " /;
PUT " kgmin1 = "; PUT kgmin.l ('g01', '05'):8:2/
PUT " kgmin2 = "; PUT kgmin.l ('g02', '05'):8:2/
PUT " kgmin3 = "; PUT kgmin.l ('g03', '05'):8:2/
PUT " kgmin4 = "; PUT kgmin.l ('g04', '05'):8:2 /;
PUT /;

PUT " ------- PGrez: ------------- " /;
PUT " PG1 = "; PUT (p.l (' g01 ',' 05 ') -kgmin.l (' g01 ',' 05 ') + kgmax.l (' g01 ',' 05 ')):7:2
PUT " PMAX = "; PUT pgmax ('g01', '05'):7:2 PUT " PMIN = "; PUT pgmin (' g01 ',' 05 '):7:2/
PUT " PG2 = "; PUT (p.l (' g02 ',' 05 ') -kgmin.l (' g02 ',' 05 ') + kgmax.l (' g02 ',' 05 ')):7:2
PUT " PMAX = "; PUT pgmax ('g02', '05'):7:2 PUT " PMIN = "; PUT pgmin (' g02 ',' 05 '):7:2/
PUT " PG3 = "; PUT (p.l (' g03 ',' 05 ') -kgmin.l (' g03 ',' 05 ') + kgmax.l (' g03 ',' 05 ')):7:2
PUT " PMAX = "; PUT pgmax ('g03', '05'):7:2 PUT " PMIN = "; PUT pgmin (' g03 ',' 05 '):7:2/
PUT " PG4 = "; PUT (p.l (' g04 ',' 05 ') -kgmin.l (' g04 ',' 05 ') + kgmax.l (' g04 ',' 05 ')):7:2
PUT " PMAX = "; PUT pgmax ('g04', '05'):7:2 PUT " PMIN = "; PUT pgmin (' g04 ',' 05 '):7:2/
PUT /;

PUT " -------- delta nagr: --------- " /;
PUT " kngr1 = "; PUT kngr.l ('n01', '05'):8:2/
PUT " kngr2 = "; PUT kngr.l ('n02', '05'):8:2/
```

```
PUT " kngr3 = "; PUT kngr.l ('n03', '05'):8:2/
PUT /;

PUT " ------- Pnagrrez: ---------- " /;

PUT " Pn1 = "; PUT (ngr (' n01 ',' 05 ') - kngr.l (' n01 ',' 05 ')):8:2
  PUT " Pnisx = "; PUT ngr ('n01', '05'):8:2/
PUT " Pn2 = "; PUT (ngr (' n02 ',' 05 ') - kngr.l (' n02 ',' 05 ')):8:2
  PUT " Pnisx = "; PUT ngr ('n02', '05'):8:2/
PUT " Pn3 = "; PUT (ngr (' n03 ',' 05 ') - kngr.l (' n03 ',' 05 ')):8:2
  PUT " Pnisx = "; PUT ngr ('n03', '05'):8:2/
PUT /;

PUT " ---------- PL: -------------- " /;
PUT " PL1 = "; PUT pkvl.l ('l01', '05'):7:2 PUT " PP = "; PUT oglp (' l01 ',' 05 '):7:2
PUT " PO = "; PUT oglo ('l01', '05'):7:2/
PUT " PL2 = "; PUT pkvl.l ('l02', '05'):7:2 PUT " PP = "; PUT oglp (' l02 ',' 05 '):7:2
PUT " PO = "; PUT oglo ('l02', '05'):7:2/
PUT " PL3 = "; PUT pkvl.l ('l03', '05'):7:2 PUT " PP = "; PUT oglp (' l03 ',' 05 '):7:2
PUT " PO = "; PUT oglo ('l03', '05'):7:2/
PUT /;

PUT " ---------- PSECH ------------- " /;
PUT " PS1 = "; PUT pksch.l ('s01', '05'):7:2 PUT " PP = "; PUT ogsp (' s01 ',' 05 '):7:2
PUT " PO = "; PUT ogso ('s01', '05'):7:2/
PUT /;

PUT " ------ Virabotka Stancii ---- " /;
PUT " WG1 = "; PUT (rvirst.l (' g01 ')):7:2 PUT " Wzad = "; PUT zdvirst (' g01 '):7:2/
PUT " WG2 = "; PUT (rvirst.l (' g02 ')):7:2/
PUT " WG3 = "; PUT (rvirst.l (' g03 ')):7:2/
PUT " WG4 = "; PUT (rvirst.l (' g04 ')):7:2 /;
PUT /;

PUT " ------ Rasxod Stancii ------- " /;
PUT " g02 = "; PUT (rasx _ rez (' g02 ')):7:2 PUT " Rzad = "; PUT zdrasx (' g02 '):7:2/
PUT /;

PUT " -------- SALJDO PS --------- " /;
PUT " PS1 = "; PUT (saldes _ rez (' es01 ')):7:2 PUT " Szad = "; PUT zdsaldes (' es01 '):7:2/
PUT /;

PUT " ---------- CEL: ------------- " /;
PUT " CEL = "; PUT f.l:10:2 /;
PUTCLOSE OPTRPS;
```

In addition, regarding the GAMS model text we can say the following:
In complete conformity with the TOR, this variant of the GAMS model combines hour intra-day hourly constraints (on capacities of stations, transfers of capacity on lines and line sections, balance of capacity of the EPP CA), as well as integrated, in daily constraints on balance transfers of PS, consumption of energy carriers and generation of electric power by stations. The absence of exactly these last opportunities in the OPTIMUM complex currently operating in UDC significantly complicates planning operative regimes of UDC in CA for a forthcoming day.

Taking into account the limited (daily) period of planning of UDC regimes in CA, a simplified approach to estimate the consumption of water on HPS or TPS is accepted in the model, namely through an average parameter, for one day, specific consumption of water / fuel of stations to generate one MWh of electric power. If necessary, the algorithm to calculate the consumption of water / fuel at stations can be specified in future.

The account of constraints on balance transfers of PS in the model, generation of the electric power and consumption of energy carriers at stations is performed with the given accuracy. The maximum admitted/ allowed deviations of settlement values of the specified parameters are defined by appropriate, for each parameter, factors of accuracy. These factors are presented as a given percent of the value of appropriate restrictive parameter.

Testing of Model Variant 2 Using an Elementary Example

The testing of the 2-nd variant of the GAMS model was carried using the same elementary example, on which the first variant of model was also tested.

For simplification of the analysis of estimations results of the model for all of 24-th hours there were accepted identical regime parameters equal to values of the 1-st variant of the model.

The daily values of balance transfers of PS, on which constraints are imposed, are defined in the model by summation of balance transfers for each PS during all hours of a day. The values of balance transfers of PS for each hour of the day are defined as the difference of hourly values of the total fixed loading of PS and the sum of settlement values of capacities of stations belonging to the PS. The sum of PS consumption by a fixed PS loading in the model is understood as loadings of unsettlement PS stations, loadings of settlement PS stations, with fixed hourly regime and external PS flows into other UDC.

The four stations, existing in the example/illustration, and three loadings are conditionally divided between 2 PS: - PS N 1 (with consumption units and stations 1 and 2) and PS N 2 (with stations 3, 4 and loading 3). Constraint on daily value of balance transfers in the example/illustration was given for PS N 1 (zdsaldes).

The constraint on electric power generation for one day were designed for station 1 depending on the consumption of energy carrier at station 2 (zdvirst, zdrasx). The specific consumption of energy carriers for station 2 was conditionally designed as equal to 2 units at 1 MWh.

The maximum allowable deviations from the given constraints on PS balance transfers, generation of electric power and consumption of energy carriers at stations are determined in the example for all three parameters at a rate of one percent from the appropriate values of restrictive parameters (zdtoch).

The results of calculations on the developed 2-nd variant of the GAMS model are given in Annex 2. They are submitted in the form of the printed result file (odcrez53.dat) formed within the GAMS model.

--------- Clock = 05 ---------
------- Delta PG: -----------
PG1 = 100.00
PG2 = 100.00
PG3 = 300.00
PG4 = 300.00

------- Kgmax PG: ----------
Kgmax1 = 1.00
Kgmax2 = 100.00
Kgmax3 = 0.00
Kgmax4 = 0.00

------- Kgmin PG: ----------
Kgmin1 = 0.00
Kgmin2 = 0.00
Kgmin3 = 50.02
Kgmin4 = 0.00
------- PGrez: -------------
PG1 = 101.00 PMAX = 100.00 PMIN = 50.00
PG2 = 200.00 PMAX = 100.00 PMIN = 50.00
PG3 = 249.98 PMAX = 350.00 PMIN = 300.00
PG4 = 300.00 PMAX = 300.00 PMIN = 200.00

-------- Delta nagr: ---------
Kngr1 = 49.02
Kngr2 = 0.00
Kngr3 = 0.00

------- Pnagrrez: ----------
Pn1 = 150.98 Pnisx = 200.00
Pn2 = 500.00 Pnisx = 500.00
Pn3 = 200.00 Pnisx = 200.00

---------- PL: --------------
PL1 = -49.96 PP = 100.00 PO = 100.00

PL2 = -50.00 PP = 200.00 PO = 50.00
PL3 = 300.00 PP = 300.00 PO = 300.00

---------- PSECH -------------
PS1 = -99.96 PP = 300.00 PO = 150.00

------ Virabotka Stancii ----
WG1 = 2424.00 Wzad = 2400.00
WG2 = 4800.00
WG3 = 5999.52
WG4 = 7200.00

------ Rasxod Stancii -------
G02 = 9600.00 Rzad = 9600.00

-------- SALJDO PS ---------
PS1 = 8399.52 Szad = 8400.00

---------- CEL: -------------
CEL = 369841.20

For each parameter in the file of results there are given settlement and boundary values. The hourly values of parameters are given only for 5th hour. The analysis of the received results confirm the following two facts:

- Hourly values of resulting parameters practically are completely identical to results received for the first variant of the model. The insignificant deviations are caused by impact of additionally introduced restrictive factors;
- Constraints on daily value of PS balance transfers N 1, development of the electric power at station 1 and consumption of energy carriers at station 2 are held with the designed accuracy.

Both these facts are the evidence of correctness of the model developed.

Modifying and Testing the OPTIMUM Complex

As in the case of model variant 1 after we had tested the algorithm on an elementary example, we conducted work to incorporate GAMS model variant 2 in the OPTIMUM complex to test and adjust the algorithm and introduce the modified complex in the operational planning practice of the EPP CA.

However, the modernization of the OPTIMUM complex to include GAMS model variant 2 in it required more labor inputs. In modernizing the OPTIMUM complex, we spent a significant part of time to solve problems of lacking RAM and adjust the GAMS model to the complex. Consequently, only by the end of the contract we managed to create a modified variant of the operational planning complex OPTIMUM. This variant allowed us to do first experimental calculations on reference and real circuits.

The calculation results on a reference circuit were absolutely identical to the calculation results on the autonomous GAMS model. We can regard this fact as the confirmed correctness of adjusting the GAMS model to the OPTIMUM complex and modifying the OPTIMUM complex as a whole.

On the real circuit of the EPP CA, we conducted several experimental calculations. For the most part, we obtained fully correct solutions. Part of results needs some additional comprehension.

We need some more time to carry out full testing of the modified OPTIMUM complex, analyze obtained results, and perhaps refine the algorithm and complex as a whole.

In addition, working on the Energy model we got additional ideas as to further development of the following aspects of this model:

- ♦ Modeling the electric regime;
- ♦ Modifying the objective function;
- ♦ Entering a series of additional technological constraints.

4. UDC Complex "OPTIMUM" Users Guide

(NOTE: OPTIMUM manual exists only in Russian. See Russian version of this report.)

Short Characteristics of the "OPTIMUM" Complex UDC "Energia"

1. Assignment of the complex

The OPTIMUM complex is assigned for operative (for the upcoming day and night) and seasonal (for vegetation and non-vegetation periods) planning of water and power energy modes of the UPS of Central Asia.

2. General information

The OPTIMUM complex is based on application of optimization model, which uses as the goal function the minimum of release cost of the power designed for UPS of Central Asia, and constrains on balance of the UPS power, existing power of controlling stations, direct and /reverse cross power flows of the controlled lines and cross sections of the lines, daily meanings of cross flow balance of energy systems (ES), production of energy power and water/fuel discharge of the controlled stations. are taken into account.

Optimization block of the complex is based on application of Gams compiler and Gams model that is designed for it.

The OPTIMUM is a finished program complex on which base there could be conducted a complex experimental and industrial tests of the developed Gams model on real UPS modes of the Central Asia. The complex is oriented to be maintained using the PC in the MS DOS 3-d and higher versions. It entirely matches the currently operating planning scheme in the UDC "Energia" and observation of water-energy modes in the UPS of Central Asia.

3. The Functioning Scheme of the Complex

The complex is designed for daily planning of water and energy modes of the UPS of Central Asia. The information used by the complex is split into standard/regulation-reference and operative information.

The following data on standard/regulation-reference (SRI) is included into the complex:

- energy systems (ES) included into UPS of the CA;
- energy unit (EU) included into ES;
- estimation stations of the UPS of the CA;
- off-design stations of the UPS of the CA;
- units of power models;
- lines of power models;
- cross sections of the lines of power models;
- intersystem cross flows;

- delivery coefficients of EU consumption to power line units.

A detailed content of SRI is shown in Annex 2. SRI is formed once-through and is corrected/amended in case of necessity. UDC "Energia" conducts tracking of SRI.

Operative information is used in the complex to produce direct estimations. It is formed per each day and night and is split into external and internal.

The external operative information is the following data received from ES and the BVO "Syr Darya".
Among data transmitted from ES are: per hour forecast consumption meanings and off-design loading of the thermal and hydro power stations on power units of the ES. Transmission of data at this stage from ES is performed with the assistance of television communication system ***Robcom***, which enables to implement transmission of files through telephone and telegraph communication lines. Information in exchange files are presented in a unified model form. Special devices of the OPTIMUM complex perform selection of data from the received files, their control, formation and transmission into ***Robcom*** (to deliver in to the ES) the receipts with the control results. In case of detection of errors among the transmitted data, the complex stipulates a possibility of its reiterated and numerous transmission.

The BVO "Syr Darya" transmits to the UDC "Energia" the recommended average meanings of water discharge on the Naryn - Syr Darya cascade HPS per month, decade or per day. These data are transmitted using post or telephone.

The internal operative information is formed directly in the UDC "Energia". The following data are in this information:

- per hour power restrictions/constrains of the UPS of the CA estimation stations;
- per hour restrictions/constrains of direct and reversed power cross flows of the controlled lines and cross lines ();
- per hour condition of (connected /disconnected) of power line models;
- day and night constrains of balance cross flows of the ES;
- day and night constrains of water/fuel discharge of the controlled stations;
- day and night constrains of power production of the controlled stations.

This information is introduced, controlled, corrected/adjusted and printed by the OPTIMUM complex devices in the form of a document, which gives/presents operative information.

After completion of the formation of all the required information, the dispatcher services of the UDC "Energia" using the OPTIMUM complex conduct estimation of the mode of the UPS of the CA for all 24 hours of the upcoming day.

The complex presents the estimation results in the following form:

- dispatcher register tasks for the UDC "Energia" dispatcher;
- dispatcher tasks for the ES;
- files for communication with technological tasks and systems reflecting the UDC "Energia" information.

The dispatcher tasks register for the UDC "Energia" dispatcher is presented in the form of a document with per hour data/ results for:

- UPS of the CA'
- ES;
- Stations;
- Power cross flows on lines and cross lines.

Among data of UPS of the CA are summary data of per hour meanings for UPS:

Consummations;

- loading;
- existing power;
- reserves for existing power;
- regulating measures.

Among data of ES are summary data of per hour meanings for ES:

- consumption
- loading;
- existing power;
- reserves for existing power;
- regulation measures;
- cross flows balance.

Among data per stations are data:

- per hour loading;
- per hour reserves for existing power;
- summary date per day of power production;
- average of water discharge in the HPS.

Power cross flows on controlled lines and cross lines are presented by per hour meanings.

Dispatcher tasks for ES are formed by the complex in the form of text files. These files are automatically transmitted into television communication system by special devices of the complex, the ***Robcom*** for their delivery to the ES. Information in the files is represented in a unified model form, enabling to automate its processing in the ES.

Summary of per hour meanings on energy system are included into data transmitted to the ES:

- consumption;
- loading;
- existing power capacity;
- reserves of available capacity;
- regulating measures;
- balance cross flows;
- intersystem power flows and cross flows for separate lines;
- loading for separate HPS.

Among transmitted data there are also summary meanings per day of the listed above parameters.

Links of the complex with technological tasks and collective information representation systems of the UDC, as it was stated above, is supported with the complex through files that are formed with resulting data.

The following are among technological tasks that use resulting data of the complex:

- dispatcher' s register;
- report.

Among the collective information representation systems of the UDC "Energia" that use resulting data of the complex are:

- technological information reflection system (TIRS);
- group management display systems (GMDS);
- graphic parameters reflection system (GPRS).

TIRS and GMDS are systems of real time, enabling to reflect in the process time "the scheduled" (i.e. resulting information of the OPTIMUM complex), alongside with tele metric information and information of the dispatcher register.

GPRS also enables to represent in the shape of graphics all three varieties of the parameters – planned parameters, tele metric parameters and data of the dispatcher register.

All three systems function within the local UDC "Energia" network and thus they are systems of the collective use.

The complete scheme of information links of the OPTIMUM complex is presented in **Annex 1.**

OPTIMUM complex is supplied with a good and friendly user's interface. Such standard devices of the user's interface as multi level function menu, the proposal menu for parameter meanings, functional keys (board), Help-prompters, analysis and comments of error situations are widely used there. The users of the complex are provided with a wide specter of service devices for inputs, reflection, corrections and printing of all types of information, that is used in the complex.