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REPORT ON THE GRID CODE FOR THE GEORGIA POWER SECTOR

Georgia Power Sector Reform
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Final Report

Prepared for:

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Energy and Infrastructure Division

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A

Report on the Grid Code for the Georgia Power Sector

Task Order 4 provides that Hagler Bailly is to provide technical assistance to assist in developing and implementing a Grid Code for the Georgia Power Sector.[1] "Grid Code," as we use the term here and as it is commonly used in Georgia, denotes the technical standards governing operation of the power system in Georgia, including equipment, planning, dispatch, stability, voltage and frequency control, reserves, and communications.

Hagler Bailly's Anatoly Lazebnik prepared the draft Grid Code after extensive consultation with counterparts at Sakenergo Dispatch, the Georgian National Energy Regulatory Commission, and the Georgian Wholesale Electric Market. As reflected in the English-language version of the attached memorandum, Hagler Bailly is circulating a Russian-language draft Grid Code to stakeholders and regulators. We expect to have Dr. Lazebnik visit Georgia again prior to the end of the Task Order, to review comments on the draft.

Attachments:

1. Technical Standards of Electric Power Wholesale Market of Georgia
2. Hagler Bailly Memorandum dated 20 August 1999, enclosing draft Grid Code to counterparts

[1] Subtask A.3 of the Task Order provides that Hagler Bailly is to "Provide technical assistance . . . including . . .developing and implementing the power market rules [and] grid code", and item V.4(f) specifies that Hagler Bailly is to submit a technical report on an "Expanded Grid Code."

B

ATTACHMENT 1

TECHNICAL STANDARDS OF ELECTRIC POWER WHOLESALE MARKET OF GEORGIA

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TECHNICAL STANDARDS OF ELECTRIC POWER WHOLESALE MARKET OF GEORGIA

Tbilisi

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TECHNICAL STANDARDS OF ELECTRIC POWER WHOLESALE MARKET OF GEORGIA

Content

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TECHNICAL STANDARDS OF ELECTRIC POWER WHOLESALE MARKET OF GEORGIA

1. General Provisions

The technical basis of the electric power wholesale market of Georgia is the Georgian energy system which is a technological complex consisting of electric power stations, transmitting and distribution networks operating in parallel and electric power consumers connected by a common operation mode and a single technological (dispatcher and automatic) control system.

The main purpose of the Georgian energy system is:

- to ensure reliable supply of quality electric power to consumers;
- to provide a technological space for effective exchange of electric power between its producers and consumers and to ensure operation of the electric power wholesale market.

2. Dispatcher Control

2.1. The Structure and Main Principles of Dispatcher Control

The structure of the dispatcher control system is based on the following principles:

- division between the dispatcher and managing functions, with dispatcher control being independent (within its functions) on administrative-economic management of energy companies;
- clear-cut division between the dispatcher and operating personnel functions of energy companies with respect to maintenance of normal operation and elimination of failure-related disturbances.
- strict dispatcher discipline implying that all wholesale market participants shall execute, without fail, all dispatcher's commands issued within the limits of his competence. If a conflict arises, it may be resolved (after execution of a command) in accordance with the Market Regulations.

Dispatcher control is based on the Regulations on Georgian Electric Power Wholesale Market Operation determining the organization structure, objectives, tasks and functions of the dispatcher control system.

Dispatcher control of the wholesale market operation serves a single purpose - ensuring most economical operation of the wholesale market with rational use of energy resources and fulfillment of the requirements concerning reliability of electricity supply and electric power quality in compliance with the Regulations on the Georgian Electric Power Wholesale Market Operation.

The dispatcher control objectives are divided into four different time levels of wholesale market operation:

- long-term planning of operation modes for a month, year;
- short-term planning of operation modes for a day, week;

- operating control of current operation modes;
- automatic control of normal and emergency operation modes in technological processes.

Long-term plans provide for the following:

- forecast of energy consumption and typical load schedules;
- development of power and electric power balances;
- optimization of plans for use of energy resources and for carrying out major repair of equipment;
- development of schemes and operation modes for specific seasons of the year (autumn-winter maximum, high water period, etc.), and in connection with commissioning of new facilities;
- solution of a complex of problems concerning higher electric power supply reliability and electric power quality levels, introduction and perfection of dispatcher control facilities and automatic control systems for normal and emergency operation modes;
- development of dispatcher instructions.

Long-term plans are regularly adjusted in compliance with changes and specified wholesale market operation conditions (consumption level, sufficiency of hydro-resources, fuel situation, etc.). Long-term planning results serve as principal limitation for short-term plans (week's or day's consumption of hydro-resources, repair capacity, etc.).

Optimization of short-term plans is based on more complete and precise information on wholesale market operation conditions, considering the said limitation.

Operating control (maintenance of current operation mode) is exercised according to daily schedules; in case of deviation from such schedules (with respect to power consumption, equipment condition, etc.), the necessary adjustment of operation mode is provided for meeting the reliability, quality and economical requirements.

Automatic control is provided by centralized and local (decentralized) systems and automatic operation control devices, relay protection devices and automatic failure prevention equipment.

2.2. Operation Modes of the Georgian Energy System

The Georgian energy system may operate in different regimes (normal, heavy, emergency and post-emergency). Each of them have different control tasks and extent of control automation and character of allocation of duties to operating personnel.

Operation	Description
Normal	Meeting the specified requirements with respect to reliability and quality of electric power
Heavy-duty (forced)	Exists for a limited time-period. Electric power reliability and quality requirements are partially lowered. Increased possibility of failure.
Emergency	To be quickly eliminated using protection and automatic equipment. In some cases, urgent steps by dispatcher and operating personnel are required.
Post-emergency	Energy system is switched to this operation mode from the emergency one. Often heavy-duty, requires personnel's interference to reduce duration of this operation mode.

2.3. Types of Operating Subordination

The Market Regulations require that all energy system elements (equipment, automatic devices and control facilities) be under control and in competence of dispatchers and senior duty personnel of electric power stations and electric power networks.

The term *dispatcher control* means such operating subordination where operations with energy system equipment are performed only on a dispatcher's instructions who controls such equipment. Equipment which operation requires coordination of actions of subordinate operating personnel is under operating control of a dispatcher.

The term *dispatcher competence* means such operating subordination where operations with energy system equipment are performed with knowledge (permission) of a dispatcher who is in charge of such equipment.

Each energy system element may be in competence of several operating managers of one and the same or different management levels.

All energy system equipment for generation, transmission and distribution of electric power is in operating competence of a duty dispatcher of the energy system or operating personnel directly subordinate to him (shift heads of electric power stations, operating personnel of electric power transmission and distribution networks, duty personnel of substations, etc).

The main equipment which operation requires coordination of actions of duty personnel of energy enterprises (energy facilities) belonging to wholesale market participants or agreed-on changes in relay protection and automatic devices of several facilities is under dispatcher control.

The principle of operating subordination is applied not only to the main equipment but also to relay protection of relevant facilities, line and failure automatic failure prevention devices, automatic normal operation control equipment and systems, as well as dispatcher and technological control equipment used by operating personnel.

Equipment which is in operating competence or under operating control of an energy system duty dispatcher shall not be put out of operation or standby mode, or put into operation without a dispatcher's permission or instruction. Energy facility managers' instructions related to the matters within dispatcher competence shall be executed by operating personnel only with a dispatcher's permission.

The energy system dispatcher service controls energy system operation ensuring consistent operation of its all energy facilities belonging to wholesale market participants.

The dispatcher service shall be responsible for proper use of the power of electric power stations, providing the maximum available power and widening of the control range. Available power and control capabilities depend on load coverage conditions, taking capacity of communication links into account.

The energy system dispatcher service is also responsible for maintaining the normal frequency. A dispatcher of the energy system ensures maintenance of specified transfer schedules for energy systems of the neighboring countries and changes the values of such transfers to maintain the normal frequency.

Control of operation of the main electric power networks with respect to voltage shall be exercised through coordinated steps of a dispatcher and operating personnel at the relevant points of the main electric power network specified in the instructions.

In case of temporary deficit of power or electric power in the energy system, the duration of load or electric power consumption limits shall be determined by the dispatcher service in compliance with the Market Regulations, and distribution of limits among consumers shall be in compliance with the Plan of Limits approved by the managers of the Georgian Electric Power Wholesale Market.

The dispatcher service shall develop and approve the main instructions on operation maintenance and operating control binding on operating personnel of energy facilities.

3. Long-term Planning of Operation Modes

3.1. General Provisions

In solving problems of long-term planning of operation modes, the dispatcher service shall perform the following functions:

- development of annual, quarterly and monthly power balances;
- development of annual and seasonal schemes for regulation of the run-off of water reservoirs and cascades of HEPS (hydro-electric power stations);
- control of regime maintenance of HEPS cascades and making necessary amendments to schedules of draw-down and filling of water reservoirs;
- keeping track on HEPS technical-economical indicators and check of efficiency of use of hydro-resources;
- making calculations and analysis of supply of fuel resources;
- participation in development of operations plans for use of various sorts of fuel and measures for maintaining energy regimes in compliance with fuel situation;
- forecast of electric power consumption and typical daily energy system load schedules in a long-term plan period;
- making calculations for energy regimes and drawing up, for specific days of the plan period, load coverage schedules required for development of drafts of optimal long-

term plans of electric power generation and transfer of power and electric power;

- consideration of technical-economic indicators and analysis of use of heat power station equipment;
- development of measures to improve electric power production structure and reduce specific fuel consumption;
- determination of permissible power values of generating equipment subject to repair in the energy system;
- preparation of proposals on optimization of plans for major and medium repairs of the main equipment of electric power stations;
- coordination of annual plans for such repairs;
- development of monthly plans for repair of equipment being under dispatcher's operating control and in dispatcher's operating competence;
- keeping control over carrying out plans for repair of equipment of electric power stations;
- determining operation schemes of the main electric power network being in operating subordination of a dispatcher;
- development of energy system operating regimes for specific seasons of the year (autumn-winter maximum, high water, summer repair, etc.), and in connection with commissioning of new facilities of the system importance;
- making calculations for flow distribution and voltage regimes in the main network;
- for specific days of a time-period (month, quarter), making calculations for optimal operation modes of the electric power network with respect to voltage and reactive power;
- determining the order of use of voltage control devices and setting voltage schedules at the points controlled by a dispatcher;
- overall control of electrical regime;
- preparation of proposals on elimination of main electric power network bottlenecks preventing rational use of the capacities and maintenance of optimal operation modes;
- analysis of the structure and dynamics of losses in electric power network;
- determining measures for reduction of losses and improvement of voltage regimes;
- development of repair plans for inter-system and main transit links being under dispatcher's operating control, control over fulfillment of such plans;
- making calculations with respect to stability, short-circuit current, asynchronous operation;
- determining maximum permissible values of power transferred by the main transit links;
- assessment of parameters of ultimate operation modes for different energy system operating conditions, as well as in connection with starting up new facilities of system importance;
- development or coordination of requirements for equipping the main network of the

energy system with relay protection, automatic line and failure prevention facilities;

- selection of relay protection and automatic equipment settings;
- coordination of settings and specifications of devices being in operating competence of a dispatcher;
- provision of volumes and settings of automatic frequency unloading (AFU) and frequency automatic circuit reclosing (FACR);
- issue of directions as to use special automatic devices for switching off the load (SALOFF);
- in case of power and electric power (energy resources) deficit over a longer period, preparing proposals on duration and volume of limitation in power and electric power with respect to consumers and proposals for development of Plan of Limits to be approved by the heads of the Georgian Electric Power Wholesale Market:
- upon approval of such limitations, enforces them and controls the fulfillment thereof;
- drawing up summary schedules for limitation in power, electric power and emergency disconnection of consumers from power supply centers.

Along with direct development of long-term operation modes, the dispatcher service shall perform other functions related to long-term planning level and optimization of Georgian energy system development, improvement of the system, methods and facilities of operating dispatcher control, equipping the energy system with automation equipment of system importance.

When performing the said functions, the dispatcher service shall prepare proposals on development of the Georgian energy system and:

- coordinate plans for putting new network facilities in operation;
- coordinate projects of development of the energy system, tasks for designing energy facilities of system importance;
- participate in development of requirements for dispatcher and technological control facilities, automatic control devices for normal and emergency operation modes;
- supervise introduction of system-purpose facilities and equipment;
- participate in development of directive materials on raising the technical level of operation of the energy system;
- arrange performance of scientific-research, design and adjustment works for improvement of reliability, economical operation of the energy system and quality of electric power;
- provide overall technical supervision over operation of communication and teleautomatic facilities;
- use equipment of the dispatcher center and dispatcher service computer center;
- develop regulations and instructions on operating dispatcher control;
- keep everyday and general accounting of operation of the energy system;
- arrange system tests for determining operation characteristics of the energy system and putting automatic operation control equipment in operation.

Generating, transmission and distribution companies shall supply the dispatcher service with all data required for long-term planning of energy system operation, including:

- proposals on power and electric power balances, expected typical load schedules;
- initial data for economical power distribution;
- desirable schedules of voltage at the dispatcher-controlled points;
- results of control measurement;
- summary schedules of emergency limitations and disconnection of consumers, etc.

3.2 Forecast

Load forecast

Forecasts for electric loads are used as initial data for all long-term planning tasks. Electric power consumption and typical daily load schedules are forecast for each interval of the relevant year (week, month) - average working day, Saturday, Sunday and Monday. Forecast shall be made for the entire energy system and individual regions.

Forecast is based on statistical extrapolation of the previous operation mode to the future. In such case, it's appropriate to consider the peculiarities of changes in load in different consumer groups (industrial, non-industrial, communal) and branches of industry. Forecast load is referred to the average monthly weather conditions (air temperatures and cloud cover are taken into account). In the forming of initial data, the actual data on load and consumption schedules are referred to nominal frequency.

Monthly consumption of electric power is determined as a total of consumption for separate days - average working days, Saturdays, Sundays, Mondays, holidays and holiday eves. For each forecast period, the reduced energy consumption calculated, with deviation of the actual frequency value from the nominal one taken into account, as well as deviation of the temperature and daylight (cloud cover) value from average values for many-years.

The maximum load shall be forecast separately.

Forecast for available and operating power

Available and operating power values of electric power stations shall be forecast for determining the balance of power and energy for the coming period (year, quarter, month, day). Gaps and limits of electric power of electric powers stations, volume of scheduled, major and current repairs (emergency power reduction shall be determined using probability calculation based on the equipment fault rates) shall be taken into account.

The said power constituent elements of electric power stations shall be forecast using both statistical methods (statistical extrapolation of the past to the future) and standard-reference materials (in particular those regulating periodicity and duration of scheduled repairs).

Depending on the long-term plan period (month, quarter, year), some constituent elements may be determined with more or less reliability.

Power of units subject to major or medium repairs are also actually determined values since such repairs are planned for a year, with the normative periodicity and duration of repair and power balance taken into account.

Power of units of heat power stations being under emergency repair shall be determined on the basis of probability characteristics for a number of years of observation.

In determining power values of available and operating power, season-related reduction of power of hydro-electric power stations caused by head decrease during spring flood-time due to higher tail-water level resulted from large water consumption, and in winter time, due to lowering head water level caused by water reservoir draw-down.

Along with forecasting the values of available and operating power required for covering the load, the volume of electric power W_Σ that can be produced by electric power stations is determined in long-term planning. In a first approximation electric power production is estimated by the number of hours during which the specified power P_{iy} was used :

$$W_\Sigma = \sum_{i=1}^{n} P_{iy} T_y$$

where: P_{iy} - specified power of equipment of certain type

T_y - number of hours during which the specified power of equipment of the certain type was used.

Forecast of reliability indicators of equipment

Reliability indicators of power and electrical engineering and control equipment in operation conditions is forecast through extrapolation or "direct application" of reliability indicators obtained on the basis of statistical data to the coming period. If such coming period is not too long (not more than 2-3 days), this method may be deemed as acceptable. However, in some cases true reliability indicators of some equipment cannot be obtained on the basis of retrospective data. It may happen, for instance, in case of lack of experience of operation of new equipment or its insufficiency for getting reliable characteristics of its reliability. Is such cases, reliability indicators of equipment can be approximately evaluated through expert assessment.

4. Short-term Planning of Operation Modes

4.1. General Provisions

In performance of its functions with respect to short-term planning of operation modes, the dispatcher service shall:

- using data of distribution networks and immediate consumers of the wholesale market, make forecasts concerning daily load schedules on the entire wholesale market and in its separate regions for the coming period of a short-term plan (from one day to one week);
- receive applications for putting in and withdrawal from operation or standby mode of equipment of electric power stations and networks, relay protection facilities, line and automatic failure prevention equipment, automatic operation control facilities being under operating control and in competence of a dispatcher;
- consider (allow, reject) such applications, determine conditions for carrying out works for most complex allowed applications;
- provide instructions as to change of scheme and preparation of operation, adjustment of permissible limits of power transferred through controlled links, use and tuning of protection facilities and automatic equipment, change of voltage schedules in control points;

- determine, on the basis of allowed applications, the maximal operating power and minimal power of electric power stations taking account of the composition of equipment, meteorological factors, operation condition of equipment and conditions of operation of electric power stations, and total operating power of electric power stations on the entire wholesale market;
- prepare power balances for morning and evening wholesale market load peaks;
- check, if necessary, power balances of the night minimum load hour, considering the maneuvering capacity of electric power stations;
- determine, for the coming short period, permissible values of electric power production of HEPS cascades on the basis of approved schedules for filling and draw-down of water reservoirs and considering the actual hydro-resources and meteorological situation;
- determine energy system operation limits with respect to use of some kinds of fuel in compliance with fuel supply plans and actual fuel supply situation.
- determine duration and number of the necessary load limits with respect to consumers in case of power and energy deficit; in compliance with the Rules of Operation of the Wholesale Market, shall enact limits plan approved by the heads of the Georgian Electric Power Wholesale Market;
- make calculations as to optimization of short-term energy regimes of the energy system, economically distributing power among electric power stations considering limits of energy resources and network operation;
- develop and approve daily schedules for energy system operation - schedules of load (power consumption) on the wholesale market, total power of electric power stations of the energy system, power transfer by links with the neighboring energy systems, values of power spinning reserve of power;
- make daily analysis of energy system operation for the past day to detect causes of deviation from the specified schedules and assessments of actions by duty dispatchers engaged in carrying out the schedule and in adjustment of operation in case of deviation of planned operating conditions.

4.2. Short-term Forecast for Wholesale Market Loads

Forecast shall be made every day, normally for each hour of the following day (for several days - before weekends and holidays). Use of weekly forecasts with their following daily adjustment is also possible.

In case of forecast for a day or a longer period (when the current day's data is unknown), loads of each hour are forecast on the basis of the relevant statistical sequences of loads of each our of several previous similar days.

In load forecasting, load forecasts by regions (distribution companies) and data on expected operation modes of big consumers are also necessary to be taken into account.

Forecasts of active and reactive loads in electric power network centers are required for supplying electricity calculating programs with information. Initial data on actual loads, in particular reactive ones, should be reduced to nominal voltage by static characteristics, and, if frequency variations took place, to nominal frequency. Forecast may be made for each hour of a day or for individual points of a daily load schedule and only for the part of network for which electricity calculations are to be made.

5. Maintenance of Normal Operation

5.1. General Provisions

Operating control in normal conditions implies control of operation mode in compliance with a specified operation schedule with adjustment of operation in case of deviation of the operation conditions from those specified in a long-term plan. When fulfilling the functions of normal operation maintenance, an energy system dispatcher and operating personnel of electric power stations make operation switching (stipulated or not by a daily plan, which became necessary in the control process), changing the scheme of electric power networks and energy facilities, and composition of switched-on equipment of electric power stations and networks (transfer to repair or reserve, putting in operation after repair or reserve).

Collection, processing and documentation of operation information shall be provided at every stage of operating dispatcher control system. Current operation control is exercised using operating control facilities, including automatic control equipment which condition and tuning are controlled by operating personnel and are changed if necessary.

5.2. Wholesale Market Energy Regime Control

Energy System Dispatcher shall:

- exercise operating control of operation of electric power stations and networks in compliance with the energy system operation schedule;
- ensure carrying out specified energy system power schedules, schedules for power transfer by links with the neighboring energy systems and spinning reserve values;
- check the fulfillment of specified daily power schedules by electric power stations;
- regulate distribution of power among electric power stations, providing adjustment of operation in case of deviation of energy system operation conditions from those stipulated in a plan;
- see to fuel supply of electric power stations, in case of a decreased in fuel supply, take measures to unload such electric power stations;
- ensure the required queues and timely starting and stopping of large units of electric power stations;
- check the fulfillment of given tasks concerning peak power and technical minimum power of units and the entire electric power station by electric power station.

Senior operating personnel of electric power stations shall:

- control power level of electric power stations in compliance with a specified schedule and dispatcher's instructions;
- supervise switching in the main scheme of electric power station, the starting and stopping of units and auxiliary equipment having affecting power consumption, reliability and economical operation of electric power station;
- ensure reliable power supply for own needs;
- control fuel supply situation.

5.3. Frequency Control in the Energy System

Dispatcher of the energy system shall:

- supervise frequency control, determining participation of an electric power station in control;
- coordinate actions of subordinate operating personnel for maintaining the required control range;
- directly supervise power consumption of big hydro-electric power stations being in his direct operating subordination;
- specify power balances of the energy system during spring and evening peak loads and, if necessary, take measures to mobilize additional power;
- determine duration of power limits and impose such limits by decision of the wholesale market heads in case of power deficit.

Senior operating personnel of electric power stations shall:

- control operation of units engaged in automatic control;
- carry out dispatcher's instructions on manual frequency control and maintenance of the required control range.

5.4. Control and Change of Scheme and Operation Mode of Electric Power Network

Dispatcher of the energy system shall:

- control and, if necessary, change the scheme and operation mode of the main(power supply) network of the energy system, ensuring reliable simultaneous operation of electric power stations, through restricting to allowed limits transfer of power by inter-system and internal transit links, as well as loads in current of equipment being under operating control of a dispatcher;
- exercise control over maintaining reliable power supply schemes of the main load units and individual responsible consumers;
- prepare the energy system for expected acts of elements;
- supervise voltage control in the energy system by ensuring maintenance of voltage at control points in compliance with specified schedules and taking measures to maintain optimal electricity regime in the main network.
- exercise control over use of reactive power;
- exercise control over the state of the energy system main equipment.

Senior operating personnel of electric power stations shall:

- ensure control of bus voltage of electric power stations in optimal reactive power distribution among generators.

Senior operating personnel of electric power networks shall:

- control the scheme and operation of a network being under their control, change, if necessary, the scheme and operation mode with respect to reliability of power supply to consumers and economical operation of a network;
- maintain voltage levels in power supply centers of a distribution network ensuring normal voltage at consumers';

- change location of voltage control devices under transformer load;
- switch on and off capacitor banks in compliance with the energy-saving and electric power quality requirements.

5.5. Putting Equipment In and Out of Operation

Dispatcher of the energy system and senior operating personnel of electric power stations and electric power networks shall:

- exercise control over withdrawal of equipment from operation (or standby mode) and its putting in operation (or transfer to the reserve) in compliance with allowed applications;
- give permission for performance of operations on equipment and devices being in their operating competence;
- prepare scheme, operating mode and automatic and relay protection equipment for work according to applications;
- direct actions by subordinate personnel in performing operations on equipment and devices being in their operating subordination;
- consider and make decisions as to carrying out urgent works beyond the plan provisions on equipment or devices being under their operating control.

5.6. Control Over Operating Control, Relay Protection and Line and Failure Protection Automatic Equipment, Putting It in and Our of Operation

Dispatcher of the energy system and senior operating personnel of electric power stations and electric power networks shall:

- control the state of relay protection and automatic equipment and systems being under their operating control and competence and the matching of relay protection and automatic equipment tuning to the network scheme and operation mode;
- monitor the state of dispatcher and technological control and computer equipment;
- take measures to eliminate faults occurred;
- putting relay protection and automatic equipment in and out of operation in compliance with instructions;
- give permission to service personnel as to putting dispatcher and technological control and computer equipment in and out of operation.

5.7. Tests. Putting New Equipment in Operation

Dispatcher of the energy system and senior operating personnel of electric power stations and electric power networks shall:

- provides operating supervision over tests in compliance with allowed applications and approved programs, as well as putting new equipment, relay protection and automatic facilities into operation.

5.8. Operation Data Transmission. Keeping Routine Accounts

Dispatcher of the energy system and senior operating personnel of electric power stations and electric power networks shall:

- receive messages on faults in operation mode, accidents with people and other incidents from subordinate operating personnel;

- in accordance with the established order, submit relevant information to next high level managers;
- keep routine accounts, noting all significant deviations of operation from the given schedule;
- ensure recording (sound recording) of operative conversations.

6. Ensuring of Energy System Reliability

6.1. Guidelines on Energy System Stability

6.1.1. General Provisions

The guidelines determine the stability requirements to be met by the energy system.

The energy system stability requirements may be changed as compared to those given in the present documents, considering specific conditions and with provision of technical-economic justification.

6.1.2. Normative Disturbances

Table 1 contains a classification of normative disturbances.

Table 1

Disturbances	Group of normative disturbances in nominal voltage networks, KV			
	110-220	330-500		
Switching off of any network element without short-circuit	1	1		
Short-circuit on electric power transmission line:				
Single-phase with successful Automatic Circuit Reclosing (ACR) (for 330 KV and higher - SACR, for 110-220 KV - TACR)	1	1		
Single-phase with successful Automatic Circuit Reclosing (ACR) (for 330 KV and higher - SACR, for 110-220 KV - TACR)*	1	1		
Multiphase with successful and failed ACR*	II	II		

Single-phase with one breaker failed and breaker failure reservation devices (BFRD) operating	II	III

*) - in case of automatic disabling of automatic circuit reclosing (ACR) and if arc does not go out, unsuccessful ACR may not be considered.

Multiphase with failure of one breaker (for 330-500 KV networks - one of breaker phases) and BFRD operation	III	III

Designed short-circuit duration is taken on the basis of the upper limit of the actual values corresponding to the main protection equipment operation. In designing, measures should be taken to ensure short-circuit duration not longer than specified in Table 1a.

Disturbances considered in energy system stability requirements are divided into three groups - I, II and III. The groups include the following disturbances:

a) switching off a network element without short-circuit and with short-circuit (See Table 1 for distribution by groups of disturbances)

b) occurrence of emergency power disbalance for any reason - switching off generator or set of generators with common breaker on the highest voltage side, at big substation or big consumer, etc. (See Table 2 for distribution by groups of disturbances).

Additionally, group III includes the following disturbances:

c) simultaneous breaking of two circuits located in a common corridor on over half the length of the shorter line in case of a disturbance of group I according to Table 1;

d) the disturbances of groups I and II with switching-off of a network element or generator which cause switching-off of other element of the network or generator connected to the same distribution facility because one of the breakers is under repair.

If during short interruption of electric power supply to a big consumer caused by short-circuit, ACR pause, etc. there may be run-out of engines followed by group self-restarting, the reactive load should be considered as one of the group I disturbances.

Table 1a

Nominal voltage, KV	330	500
Short-circuit switching-off time, sec	0.14	0.12

Table 2

Power emergency disbalance values	Group of normative disturbances
Not more than that of generator or generator unit power except most powerful	I

Not less than the disbalance for group I but not more than the generator or generator unit peak power in the energy system — II

Not less than the disbalance for group II but not more than:

1) power of buses or distribution unit connected to one section (system) of the same voltage of electric power station — III *

* - emergency disbalances of group III are referred to the case where stability of parallel operation through links with the energy systems of the neighboring countries is considered.

2) 50 % of power of electric power station

6.1.3. Static Stability Margin Coefficient of Active Power in Section

The static stability margin coefficient of active power in section (Kp) is calculated according to the following formula:

$$Kp = \frac{Ptp - P - \Delta P}{P} \qquad (1)$$

where: Ptp - active power transferred through the section under consideration (transfer in section) in a mode that is ultimate in terms of static stability;

P - transfer in section in operation mode under consideration, $P>0$;

ΔP - range of non-regular fluctuations in active power in this section in the operation mode under consideration (it's assumed that transfer P varies in the range $P \pm \Delta P$).

Transfer limit in section with respect to static stability is determined through increasing operation mode load (transfer increase). In this case, load trajectories which are sequences of existing operation modes allowing, if some parameter or group of parameters is changed, to reach the boundary of statistic stability area are considered.

An increase of transfer in section for a number of load trajectories which are typical of the energy system and differ in redistribution of power among units located on each side of a given section should be considered. The value Ptp is determined by the trajectory to which the lower power limit corresponds.

Only power balanced ways of increasing load of an operation mode, i.e. where frequencies remains actually unchanged, are allowed. If in some conditions, a transfer increase may be caused or accompanied by a significant change of frequency, such ways of making an operation mode heavier should not be considered.

The transfer limits in terms of static stability should be determined considering generator overload in current of rotor allowed within 20 minutes.

Large overload is allowed to be considered (in all operation modes, except an emergency one) if, in the permitted time, such overload is automatically cleared without reduction of stability margin in section (automatic starting of hydro-generators, their switching from a compensatory mode to an active one, etc).

The range of non- regular fluctuations of active power (ΔP) in the given section, (1) is set for each section of the energy system on the basis of measurement data.

In case of the absence of such data, the designed range of non-regular fluctuations of active power, MW, can be determined using the following expression:

$$\Delta P = K \frac{P_l 1 * P_l 2}{P_l 1 + P_l 2} \qquad (2)$$

where $P_l 1$, $P_l 2$- total load power on each side of the given section (MW);

coefficient K is assumed as equal to:

1.5 - manual control

0.74 - automatic control and limitation of power transfer.

In operation, control of active power transfer values should be normally used to control the observance of normative static stability margin.

If necessary, the maximum permissible and emergency permissible transfer are set as functions of transfer in sections and voltage in the central points of the energy system. Such transfer and voltage should be included in controlled parameters.

Depending on specific conditions, other parameters of energy system operation may be used as controlled, in particular the values of angles between voltage vectors at electric power transmission ends. Permissible values of controlled parameters ensuring a normative active power margin coefficient should be determined through calculations.

6.1.4. Load Center Voltage Margin Coefficient

The values of voltage margin coefficient (Ku) are referred to load centers and calculated according to the formula:

$$Ku = \frac{U - Ucr}{U} \qquad (3)$$

where U - load center voltage in a given operation mode;

Ucr - critical voltage in the same center corresponding to the boundary below which engine static stability is disturbed.

The load center critical voltage of 110 KV and higher should be assumed as not lower than 0.7 Unom and 0.75 norm where Unom - nominal voltage and Unom - voltage in the given load center in normal operation.

To control the observance of the load center normative voltage in operating practice, voltage in any network load centers of the energy system may be used. The voltage permissible values in controlled centers are determined through calculations for energy system operation modes.

6.1.5. Energy System Stability Requirements

Minimal coefficients of static stability margin with respect to power in sections and voltage in load centers are rated according to energy system stability conditions. Also, groups of disturbances ensuring both dynamic stability and rated coefficients and static stability margins in post-emergency operation modes are determined.

These requirements can be fulfilled through:

- enhancement of electric power network;

- reduction of short-circuit switching-off time, improvement and optimization of setting of ACR devices (for instance, control of the extinguishing of arc in ACR pause, selection of placing electric power transmission lines under voltage, change in duration of ACR pause), etc.
- use of systems and devices of automatic stability disturbance prevention;
- change of energy system operation mode.

Dead-beat static stability coefficients are rated provided that the absence of self-swinging should be ensured in the allowed area of operation modes. If self-swinging arises, measures should be taken to eliminate the causes of it and the section where oscillations are observed should be immediately additionally unloaded to stop such oscillations.

Also, for allowed transfer, the absence of thermal overload of equipment, considering the time of operation mode existence and other existing limits not connected with the energy system stability should be checked.

The values of stability indicators should be not lower than those given in Table 3.

Table 3

Transfer in section	Minimal active power margin coefficients, Kp	Minimal voltage margin coefficients, Ku	Groups of disturbance which require ensuring stability in section	
			in normal scheme	in repair scheme
Normal	0.20	0.15	I, II, III	I,II
Heavy-duty	0.20	0.15	I, II	I
Forced	0.08	0.10	-	-

In designing an energy system with normal scheme and normal transfer, in case of disturbance of group I in a network of 500 KV and below, stability should be ensured without use of automatic failure prevention devices, except the cases where:

- fulfillment of the requirement makes it necessary to limit consumers or results in loss of hydro-power resources;
- disturbances result in the static stability limit being reduced by more than 25 %.

Automatic failure prevention equipment is allowed to be used for trigger circuits of facilities to prevent stability disturbance in case of group I disturbances.

After normative disturbances, post-emergency operation mode should meet the following requirements:

- active power margin coefficients should be not less than 0.08;
- voltage margin coefficient - not less than 0.1.

The duration of post-emergency operation mode depends on the time during which a dispatcher restore the normal operation condition, usually not more than for 15-20 minutes.

During this time, additional disturbances, if occurred, (i.e. overlapping failures) are not considered.

In case of disturbances which cause the weakening of a section, stability may not remain (except in conditions specified in the following cases:

- dead-beat static stability limit in links remaining in section is not higher than the range of non-regular power fluctuations in this section.

In this case, division by links remaining in operation should not result in failure cascade development if automatic failure prevention devices operate properly.

In the said cases, the energy system should be automatically divided by this action till asynchronous operation arises or at its initial stage.

In operation, any deviation from the requirements concerning the normal transfer (the first line in Table 3) means switching over to forced transfer and shall be allowed by a dispatcher who controls the links of this section and in whose competence they are. Switching over to forced transfer in the section for the time of maximal load, but not more than for 40 minutes, or for the time required for imposition of consumer limits, and in post-emergency operation, also for the time required for mobilization of the reserve (including cold one) can be urgently carried out after permission by a duty dispatcher.

Operation with forced transfer shall not be allowed if stability disturbance in this operation mode with disturbances of groups I and II and proper operation of automatic failure prevention equipment may result in disconnection of consumers from AFU and BFRD of the total power of over 10 times more than the consumer limit value required to ensure normative indicators of normal transfer.

Automatic termination of asynchronous modes in the energy system, normally, through its division, should be provided. Re-synchronization using automatic devices and spontaneous one should be reserved by division.

The allowed duration of asynchronous mode and way of its termination should be determined for each section considering the necessity of prevention of damage of energy system equipment, additional disturbance of synchronous operation and interruption in electric power supply to consumers. Special attention should be paid to stability of electric power stations and large load centers near which a center of swinging is possible to occur.

6.1.6. Calculation Check of Fulfillment of Energy System Stability Requirements

Calculations for energy system stability and calculation check of measures for its insurance are a necessary part of design and operation of the energy system.

Calculations for stability are made:

- in selection of the energy system main scheme and in specifying the location of the main equipment;
- in selection of operation modes of the energy system;
- in choosing measures for increasing stability of the energy system, including automatic failure prevention facilities;
- in determining the parameters of setting the adjustment and control systems, relay protection equipment, ACR;
- in determining parameters of setting of automatic failure prevention systems designed to enhance stability of energy system;
- in check with respect to compliance with the normative indicators of stability and other requirements.

Additionally, calculations for stability should be made in development and specifying of the requirements concerning the main equipment of the energy system, relay protection, automatic equipment and control systems for energy system stability conditions.

Below are discussed the matters concerning check of compliance with the normative requirements, including calculations for established normal and post-emergency operation modes, assessment of their static stability, determination of ultimate stability operation mode, calculation of static stability margin coefficients, determination of stability in case of normative disturbances (calculations for dynamic stability).

Calculations for established operation modes

In checking energy system stability, the operation modes corresponding to typical points of daily and seasonal power generation and consumption schedules in possible normal and repair schemes. These modes should be considered as long existing.

In calculation for established modes, generators should be presented as constant voltage sources (in design point of voltage maintenance) with specified active power. The minimal and maximum values of available reactive power are recommended to be set on the basis of voltage and active power values in the given operation mode. Fixed reactive power (instead of voltage) may be set.

Load centers should be normally expressed by voltage-independent active and reactive power values.

Post-emergency operation parameters should be obtained on the basis of all changes caused by transition process, including operation of automatic failure prevention devices, overload limits of excitation winding of generators and synchronous condensers. In case of power disbalance, frequency variation should be taken into account.

In calculations for post--emergency operation, load centers should be expressed by static voltage characteristics and in case of frequency variation, for generators and load, their static characteristics should be considered.

Calculations for energy system static stability

If the area of dead-beat static stability is close to the area of operation mode existence, checking the existence of an operation mode is allowed to be confined to.

In calculations for dead-beat static stability, if the condition $U>Ucr$ is violated in any load center, the corresponding operation modes should be regarded as periodically unstable.

Calculations for oscillation stability should be made for:

- in operation, if data on possible occurrence of continuous or poorly damping oscillations is available, for specifying the areas of allowed modes and determining the efficiency of measures aimed at prevention of oscillation disturbance of stability;
- in designing, if problems with ensuring oscillation stability are expected, in particular if new equipment, such as generators, excitation systems and ARV will be used at an electric power station.

In most of cases, in checking dead-beat stability, generators are allowed to be expressed by constant voltage sources (at design points of voltage maintenance depending on ARV type) with specified active power, and load - by static characteristics without taking transformer voltage control taking into account.

Determining ultimately stable operation modes

For determining the coefficient of active power stability margin in section, a mode is made heavier through increasing a power transfer in section until the ultimately stable mode is obtained.

The trajectories of increasing the load of mode should maximally change the mode in a specified section. Calculations for heavy modes is accompanied by checking their static dead-beat stability.

To increase transfers in a given section, it's recommended in calculation to load generators on one side of the section and unload on the other side. When maximal and minimal generator power limits are reached, further increase of transfer is recommended to be made with a respective decrease or increase of load active and reactive power. If load is reduced down to the minimum possible in real conditions, for further increase of transfer, generators should be re-loaded with the corresponding limits lifted (with respect to current of generator starter, current of transformer, power of assembly or energy unit, etc., except rotor current limits).

If a given section connects two parts of the energy system, with the smaller part being a deficit one, an increase of energy system deficit part load should be regarded as the main way of making a mode heavier in this section.

If other factors causing an increase of transfer are typical of specific conditions, such ways of making a mode heavier should be also considered.

In case of increasing a load of a mode, generators are allowed to be presented in the same way as in calculations for established operation mode, the above generator reactive power limits should be taken as given above.

Generator active power alteration under the action of secondary control system is taken into account, if necessary. All automatic control devices preventing ultimate transfer in this section (automatic transfer limitation, automatic failure prevention devices) should be assumed as switched off.

Large load centers located at the energy system points where significant voltage alterations (over 5-10%) are possible in increasing a load of an operation mode should be expressed by static characteristics. For other loads, it's allowed to assume Pl= const, Ql+ const.

In case of making an operation mode heavier through load increase, an increase of reactive load in the absence of actual data is recommended to assume as proportional to the active load increase with the proportionality coefficient of 0.5.-0.7 Mvar/MW.

Considering load increase trajectories with significant frequency variation, power static characteristics with respect to frequency should be additionally taken into account for generators and load.

The determining of critical voltage in load center has the following peculiarities.

If a load center includes synchronous engines operating with ACR being switched off, critical voltage should be taken as 0.85 Unom; calculations based on the parameters of the engines and their excitation systems are required for specification.

If a load center contains specific electrical receivers (for instance, direct current electric drives), the Ucr values should be set in accordance with the relevant standards.

If a load center contains long or too loaded lines of a distribution network (not included in the energy system design scheme), critical voltage should be specified through calculations according to a special calculation scheme. This scheme includes: distribution network powered by the given center, voltage control of step-down transformers, static voltage characteristics of all main groups of electrical installations and their critical voltage values. The energy system outside part to the center is not considered, the given center is assumed as balancing center (BC). In the first calculation, the BC voltage is assumed as equal to normal voltage in this center. In the following calculations, BC voltage steps down with every following calculation.

Critical voltage is assumed as equal to balancing center minimal voltage at which load center static dead-beat stability remains, but not lower than the above Ucr values.

Calculations for dynamic stability

In calculations for dynamic stability of generators close to a short-circuit point, design models considering electromagnetic transition processes in excitation winding and damping circuits, and transitional processes in excitation systems, including ARV, should be applied.

In calculations for short-term transition processes, power of turbines is allowed to be assumed as constant.

In calculations for dynamic stability for large load centers (in particular those located near generators modeled in detail and in sections which may cause disturbance of energy system stability), equations of asynchronous and synchronous engines should be used if consumed power of the latter is significant.

For other load centers, it's normally allowed to use static characteristics in those centers where voltage decrease in transitional operation mode (after switching-off of short-circuit) is not more than 5-10 %, it's allowed to express load as constant resistance, and for centers remote from short-circuit point - by constant power or take it into account in the balance of generating centers.

The self-disconnection of electrical receivers in case of great voltage decrease should be also taken into account.

The check with respect to compliance with stability requirements in case of normative disturbances should be carried out considering operation of automatic failure prevention devices designed for automatic stability disturbance prevention (ASDP), i.e. should include checking the ASDP efficiency.

Design models of the energy system are specified on the basis of operation experience and through carrying out full-scale experiments.

6.2. Relay Protection and Reservation Devices in Breaker Failure Conditions

All elements of the main electric power system of the voltage of 220-500 KV (lines, transformers, automatic transformers, buses) should be equipped with main rapid-operating relay protection devices (RP) which time of coming into action is not more than 20-25 ms and the total short-circuit switching-off time, including the time of breakers being off (50 ms) - 80 ms.

Relay protection devices should disconnect a failure section using all necessary reservation facilities since energy system cannot operate without short-circuit section being disconnected.

To disconnect a short-circuit section in case of failure of main relay protection facility or breaker of an air line (AL) (or transformer), various reservation facilities and methods are used: **long-distance** - at neighboring sub-stations and **short-distance** - at the "own" substation.

Remote reservation facilities include: reserve multi-stage relay protection facilities against inter-phase (remote) and earth-short-circuit (directed, current, zero sequence); remote switching-off (transmission of commands on opening a breaker located on the other end of the line) with operation of the first remote relay protection (RP).

With extension of energy system, remote reservation of adjoining elements through relay protection becomes difficult or inefficient as the necessary sensitivity, required quick short-circuit switching-off and non-selective switching-off of a large number of connections.

Short-distance (local) reservation facilities include: reservation device in breaker failure conditions (BFRD); duplication - use of two and sometimes three main relay protection devices (usually of different types, e.g. phase-differential and remote with transmission of remote switch-off commands) connected to different current and voltage transformers, different automatic switches (fuses) and acting on different coils of switch opening.

Microprocessor complexes containing, besides relay protection facilities, technical diagnostics facilities and emergency data recording devices will be used on a broader scale in future. Failure data base allows to improve both operating analysis of failures and retrospective analysis for assessment the correctness of failure prevention measures and direct failures of automatic equipment.

6.3. Automatic Circuit Reclosing

All air lines and most of buses of the main network substations should be equipped with ACR devices. Along with three-phase ACR (TPACR), single-phase ACR (SPACR) and combined ACR (CACR) operating when one phase is off (in case of single-phase short-circuit) should be used on super-high voltage lines as SPARC and if three phases are off (in case of inter-phase short-circuit and improper relay protection facility operation) as TPACR.

By restoring operation in case of unstable failures, false or excessive operation of line or bus relay protection facilities, ACR contributes to prevention of failure developments, restoration of normal network scheme.

6.4. Automatic Failure Prevention Equipment

6.4.1. General Provisions

To prevent occurrence and development of failures in the energy system and to speed up restoration of normal operation, automatic failure prevention devices should be used. Their use makes it possible to prevent system failures accompanied by interruption in energy supply to consumers on a large territory.

The complex of automatic failure preventive devices consists of several subsystems performing the following functions:

- automatic stability disturbance prevention (ASDP);
- automatic asynchronous operation termination (AAOT);
- automatic frequency decrease limit (AFU);
- automatic voltage decrease limit (AVU);
- automatic frequency increase limit (AFIL) and automatic voltage increase limit (AVIL);
- automatic equipment unloading (AEU).

Automatic failure protection devices should perform the following functions with respect to the total controlled features:

- to assess the state of the energy system ;
- to detect the presence and assess the graveness of an emergency disturbance;
- determine the necessity and required intensity of control actions (CA)

6.4.2. Control Actions of Automatic Failure Prevention Equipment

Automatic failure prevention equipment perform the following main control operations:

- turbine unloading (TU);
- switching-off of generators (SOG);
- load switching-off (LOFF);
- program- forced generator excitement (FE);
- compensation of forcing (CF), switching-on of shunt reactors (SRON), switching-on of shunt reactors (SROFF);
- energy system division (SD) into asynchronously operating parts;
- switching- off of individual electric power transmission lines and communication transformers, opening of sectional and inter-bus switches not leading to SD;
- switching-on of previously switched-off load, normally switched-off electric power transmission lines, transformers, switches;
- electrical inhibition of generators;
- unloading and loading of hydro-turbines.

Control actions (CA) are recommended to be dozed by stages. i.e. control action of some intensity according to the corresponding signal.

Considering possible damage, it's expedient to use certain queues in ACs, depending on the aim of the action and type of automatic failure prevention equipment. In selection of CA, the condition of electrical engineering and energy equipment is necessary to be taken into account.

Unloading of Turbines

Two ways of unloading of steam turbines are used - short-term and long-term ones.

Short-term (pulse) unloading of steam turbine (STUT) is quick lowering of turbine power as a result of closing control valves for several seconds. It's used in automatic stability disturbance prevention to reduce excessive kinetic energy of unit rotors at the initial stage of transitional process caused by failure-related disturbance. Intensity of action is characterized by quick and high unloading.

Long-term unloading of steam turbine (LTUT) or power limitation (PL) are a long-term (for the time of existence of post-emergency operation) reduction of power as a result of closing of turbine control valves and, accordingly, decrease of boiler unit output.

LTUT allows :

- to prevent stability disturbance;
- to terminate asynchronous operation mode;

- to limit equipment overload.

Switching-off of generators (GOFF) is used for:

- prevention of stability disturbance;
- termination of asynchronous operation;
- limitation of increase of frequency and overload of equipment.

Generators are switched off by opening the switches of generators or generator units-transformers. Switches to be opened should be selected with the following taken into account:

- ensuring the necessary speed and reliability of opening;
- number of generators that are switched off when relevant switches are acted on;
- high-voltage circuits of electric power station.

In selecting a CA, it's required to consider that switching- off of generators:

- is more preferable on HEPS than on heat power stations;
- expedient on heat power stations only after the power limitation capabilities are exhausted.

In selecting the generators to be switched off, the possibility of operation of units with the generators operating onto the load of own needs should be taken into account.

Switching- off of load (LOFF) is used for:

- frequency and voltage decrease limitation;
- stability disturbance prevention;
- termination of asynchronous operation;
- equipment overload limitation.

As LOFF directly depends on shortage in energy supply to consumers, ACR is recommended to use after LOFF.

7. Prevention and Elimination of Failure-Related Disturbances

7.1. General Provisions

Distribution of failure prevention and liquidation functions is determined by dispatcher instructions, taking into account:

- different schemes and operation modes of energy facilities;
- particular equipment features;
- extent of equipping with operating control facilities;
- automation level and a number of other factors.

Distribution of these functions is affected by two conflicting factors:

- the desire to give operating personnel most possible independence in liquidation of rapidly developing system failures covering an increasing number of facilities where the personnel should act quickly and, where, in most cases, it's actually impossible to get timely instructions from a dispatcher;

- the necessity of restriction of independent actions of personnel of electric power stations as to emergency power control when, in a complicated situation, it may result in development of failure.

Clear-cut function distribution among personnel of different operating control levels on the basis of most possible independence of subordinate personnel and strict dispatcher discipline are the essential conditions of timely prevention of failures and their urgent liquidation. All instructions of a dispatcher should be immediately fulfilled (except instructions threatening safety of people and equipment and posing an evident threat to electric power stations).

In liquidating local failures, operating personnel should, if possible, maintain contacts with the next higher level operating supervisor (depending on the character of subordination and belonging of equipment). An energy system dispatcher, should have the right to interfere, if necessary, in the process of liquidation of failure of the equipment which is not under his operating control.

Local instructions specify independent actions to be taken by personnel only in case of loss of communication or regardless of existence of communication with the next-higher-level operating supervisor. Lack of communication implies not only communication failure but also the impossibility to communicate with the higher-level supervisor within several (two-three) minutes. It means that in case of serious system failures, a significant part of local personnel should act as if communication is lost. The local instructions also specify the operations which are not allowed to perform without instructions (e.g. switching-on without checking synchronism of lines and transformers which are not allowed to be switched on asynchronously, applying of voltage to switched-off lines which, under instruction, should receive voltage from other facilities, etc.).

For the purpose of most rapid liquidation for such failures, a dispatcher, first of all, should:

- find out the energy system condition;
- identify the type of scheme fault, operation mode and (if possible) the fault causes;
- question and instruct personnel of main facilities as to most rapid liquidation of failure.

In the failure liquidation process, a dispatchers shall act ignoring insignificant messages from subordinate personnel and relying on their independent actions prescribed by local instructions. Actions of operating personnel of different control levels required for prevention and liquidation of failures in the energy system are listed below.

7.2. Chance Frequency Decrease by 0.1-0.2 Hz and More

<u>Energy system dispatcher shall:</u>

- find out causes of frequency decrease;
- give instructions to shift heads (duty engineers) of HEPS of immediate operating subordination as to use of spinning reserve for restoration of the normal frequency, taking the loading of links with the neighboring energy systems into account;
- give instructions to shift heads of heat power stations of immediate operating subordination as to use of power spinning reserve within the permissible load limits of controlled links.

Senior operating personnel of electric power stations and electric power networks shall take measures to increase power of electric power stations through use of spinning reserve, line load control; act independently at those electric power stations where such actions are allowed by local instructions, and at other electric power stations - on instruction (with permission) of an energy system dispatcher.

7.3. Further Frequency Decrease Below 49.5 Hz

Energy system dispatcher shall:

- give instructions to shift heads as to full use of spinning reserve and starting standby hydro-generators, and, if such measures are not sufficient, on unit power increase up to the values corresponding to permissible overload (taking controlled links load into account).

Senior operating personnel of electric power stations shall:

- increase power of electric power stations through full use of spinning reserve, starting standby hydro-generators, switching the hydro-generators from synchronous condenser mode into active power output mode, increase of electric power of heat units, using permissible equipment failure-related overload, but avoiding dangerous overload of controlled lines; act independently at those electric power stations where such actions are allowed by local instructions, and at other electric power stations - on instructions (with permission) of an energy system dispatcher.

7.4. Long (Despite Measures Taken) Frequency Decrease below 49.5 Hz Lasting for 15-20 Minutes

Energy system dispatcher shall:

- determine the necessary volume of swich-offs, distribute such volume among distribution companies and give instructions as to disconnection of consumers.

Senior operating personnel of electric power stations and electric power networks shall:

- disconnect consumers on energy system dispatcher's instruction.

7.5. Sharp Frequency Reduction (Despite ACR operation, Frequency Remains at the Level of 49 Hz and Below Lasting for 3-5 Minutes)

Energy system dispatcher shall:

- disconnect consumers, considering priority of their disconnection.

Senior operating personnel of electric power stations and electric power networks shall:

- disconnect consumers on dispatcher's instruction; in case of great frequency decrease (48-45 Hz) of electric power stations, independently allocate own needs for asynchronous power supply (if the relevant automatic equipment is not available or failed), where the instructions stipulate that; in some cases, in compliance with local instructions, independently separate electric power station with local load.

In failures where frequency is decreased to 49.5-49 Hz and below (but higher than 48.5 Hz), operating personnel act independently or on dispatcher's command as specified by dispatcher instructions. This is due to the fact that energy system dispatcher is authorized to forbid independent actions of subordinate operating personnel for frequency restoration if such actions may result in failure development because of inadmissible overload of transit links. At the same time, in some cases, independent actions are necessary (e.g. if a dispatcher knows that frequency decrease is caused to generating power loss in the energy system and if mobilization of power reserves won't result to dangerous overload of inter-system or internal system transit links).

Operating personnel should take into account that in case of significant decrease of frequency, its temporary stabilization may be caused by such increase of generated power (due to operation of automatic turbine rotation frequency controls) at which rapid lowering of steam parameters may begin. If, despite measures taken to force operation of boilers, inadmissible reduction of steam parameters occurs, electric power station personnel shall unload the turbine unit to maintain these parameters at the admissible level.

The description of personnel's actions in case of chance frequency decrease indicate that in initial normal operation, frequency should be maintained as at the level not lower than 49.8 Hz. If heavy-duty operation with a frequency lower than 49.8 Hz preceded a failure, actions specified above for chance frequency decrease by 0.1-0.2 Hz should be taken in case of chance frequency decrease by 0.1 Hz and below, and frequency limits, in case of further frequency decrease, should be set 0.5 Hz lower than specified in these items (49 and 48.5 Hz respectively).

In initial operation mode with a frequency below 49.8 Hz, measures to liquidate failure-related frequency decrease should ensure frequency increase approximately up to the level at which it was maintained before the failure. In case of significant losses of generating power, if, despite ACS operation, frequency remains at the level of 48.5 Hz and below, all restrictions as to personnel's independent actions for urgent mobilization of power reserves should be lifted and energy system dispatcher, after three-five minutes (the time required for use of all power reserves by operating personnel of electric power stations), independently disconnects consumers according to the queue.

Operating personnel of electric power stations where power was automatically increased with a frequency decreased should inform energy system dispatcher about that and operating personnel of heat power stations should additionally take measures to restore the parameters through forcing steam output of boilers.

In frequency restoration, manual re-connection of consumers disconnected during a failure may be made with energy system dispatcher's permission. In failure liquidation, frequency should be increased 0.1 -0.2 Hz higher than the upper frequency ACR (FACR) setting. If it's impossible to achieve, energy system dispatcher should give a command as to manual connection of consumers which were not re-connected by FACR, avoiding repeated frequency decrease.

7.6. Voltage Decrease Below Permissible Normal Levels at Energy System Control Points

Energy system dispatcher shall:

- step up voltage on buses of electric power stations and substations up to permissible levels;
- if necessary, change the network sectioning schemes;
- redistribute reactive power flows using devices of voltage control under load in transformers;
- switch off reserve reactive power sources;
- switch off shunting reactors.

Senior operating personnel of electric power stations and electric power networks shall:

- to independently step up voltage at controlled points (without waiting energy system dispatcher's command), use reactive power reserves and local voltage control facilities.

7.7. Further Voltage Decrease (Despite Mobilization of Reactive Power Reserves) and Chance Sharp Voltage Secrease to Set Emergency Limits

Energy system dispatcher shall:

- take all necessary measures to eliminate the causes of failure-related voltage decrease;
- ensure the possibility of timely elimination of failure-related overload of generators and synchronous condensers (SC);
- redistribute active power and unload generators overloaded in current through reduction of their active power;
- order to disconnect that number of consumers that is required to prevent failure if the measures taken are not sufficient;
- give instructions on reactive load increase on generators and SCs up to permissible values;
- take other measures required to step up voltage at dispatcher-controlled points;
- in compliance with the Market Regulations, disconnect consumers in those parts of the energy system where voltage values are the lowest if voltage remains at or below the emergency limit and the permissible time of emergency overload of generators and SCs is exhausted.

Senior operating personnel of electric power stations and electric power networks shall:

- independently cause permissible emergency overload of generators and SCs to step up voltage at the personnel-controlled point (with following notification of energy system dispatcher);
- disconnect consumers by energy system dispatcher's command.

7.8. Dangerous Overload of Inter-System and Internal System Links

Energy system dispatcher shall:

- in case of overload of links, remove overload by increasing generated power in the receiving part and decreasing power in the transmission part;
- if necessary (lack of reserve in the receiving part, operation at lower frequency, etc.), order to disconnect consumers in the receiving part.

Senior operating personnel of electric power stations and electric power networks shall:

- in cases stipulated by local dispatcher instructions, acting independently, take measures to eliminate dangerous overload of personnel-controlled lines.

7.9. Operation Disturbance Due to Uncleared Short-Circuit

Energy system dispatcher and senior operating personnel of electric power stations and electric power networks shall:

- detect short-circuit place on the bases of control board instrument readings, analysis of relay protection operation and polling of operating personnel;
- disconnect the short-circuit section using adjoining switches of power supply connections if the switch of the damaged element cannot be opened.

7.10. Energy System Asynchronous Operation

Energy system dispatcher shall:

- detect the approximate swinging center;
- take urgent measures to equalize frequencies in asynchronously operating parts of the energy system allowing frequency decrease down to the values specified in dispatcher instructions (not lower than the upper setting of AFC) in redundant parts;
- urgently disconnect part of the consumers in case of lack of reserve in the deficit part and frequency decrease below 48.5 Hz;
- separate the asynchronously operating parts if synchronism cannot be restored within two-three minutes;
- carry out the necessary preparation and synchronization of the parts operating separately;
- restore normal operation parameters.

Senior operating personnel of electric power stations shall:

- acting independently, alter electric power station power to restore normal frequency in case of asynchronous operation and deviation of frequency from the normal one;
- further adjust electric power station power (if not specified otherwise in the local instructions), if asynchronous operation persist after normal frequency has been restored;
- increase voltage up to permissible limit if it's specified in local dispatcher instructions.

7.11. Sharp Frequency Increase Above 50.5 Hz

Energy system dispatcher shall:

- find out the causes of frequency increase, condition and operation mode of the main network (sharp frequency increase is most likely if energy system parts redundant in power are separated);
- take measures to decrease frequency through unloading, first, HEPSs and then heat power stations, avoiding overload of internal system links and links with energy systems of the neighboring countries;
- control actions of subordinate operating personnel for frequency decrease.

Senior operating personnel of electric power stations shall:

- independently reduce generated power of hydro-electric power stations (in some cases, also heat power stations) by decreasing frequency down to 50.5 Hz;

7.12. Further and Chance Increase of Frequency up to 51.5 Hz and Above

Energy system dispatcher shall:

- act as specified above.

Senior operating personnel of electric power station shall:

- independently, on hydro-electric power stations (in some cases, also on heat power stations), urgently decrease generated power by switching off some of the units until frequency decreases down to 50.5. Hz (considering the conditions of remaining supply for own needs of electric power stations and following re-start of the units).

7.13. Emergency Division of Energy System into Asynchronously Operating Parts with the Possibility of Loss of Voltage in Some Separated Parts

Energy system dispatcher shall:

- identify the nature and causes of failure, condition of inter-system links and the main networks of the energy system, points of its division;
- find out into which parts the energy system was divided and frequency and common voltage level in the separate parts;
- detect network sections and electric power stations left without voltage in division of the energy system with power removed;
- identify electric power stations where own needs were separated for asynchronous power supply;
- find out the condition of other generators (not allocated for own needs), the possibility of turning hydro-generators together with own needs mechanisms;
- independently take measures to urgently synchronize the divided parts, restore frequency and voltage ensuring, first of all, prevention of complete loss of own needs of electric power station, stability disturbance and damage of the main equipment;
- switch network sections from the deficit part to the redundant one with short (permissible) interruption in power supply;
- separate generators form the redundant part for synchronization with the deficit part;
- asynchronously switch the divided parts to parallel operation at permissible frequency difference, which is allowed by dispatcher instructions;
- disconnect consumers to increase frequency up to the level allowing to ensure synchronization if the deficit part frequency cannot be increased using the said methods;
- urgently take measures ensuring the possibility of feeding voltage from the main network of the energy system to a separated part of the energy system in case of complete loss of voltage in that part;
- if there is a sufficiently powerful HEPS in the energy system part with power removed, give command to turn the stopped hydro-generators, their switching them to parallel operation on the allocated bus system (using synchronization method) and to apply voltage triggered off from these buses to the energy system by most powerful link (with the following switching in of the other links);
- if voltage cannot be applied to the entire de-energized energy system, divide it into parts and apply voltage to separate sections, urgently connecting electric power stations where rapid synchronization of switched-off generators is possible, ensuring resumption of power supply to most important consumers;
- take measures for rapid turning of electric power stations left without voltage, above all powerful electric power stations, using generators allocated for own needs (and local load) as power supplies.

- apply voltage to the entire energy system or its parts in turn, depending on the restored power level and scheme conditions;
- in cases specified by local dispatcher instructions, use the possibility of voltage increase in the de-energized part with simultaneous synchronization of generators the power of which is comparable with the power of connected consumers;
- after applying of voltage, ensures the turning and re-connection of the equipment of other electric power stations;
- in the failure liquidation process, control frequency and voltage preventing their decrease with growth of consumed power up to the level where operation of own needs mechanisms is disturbed;
- if necessary, without instructions given, additionally disconnect consumers (in compliance with the Market Regulations)

Senior operating personnel of electric power stations and electric power networks shall:

- inform energy system dispatcher about occurred operation and scheme disturbance of the system nature;
- fulfil dispatcher's commands for restoration of normal scheme and operation;
- in compliance with local dispatcher instructions, takes independent actions to restore frequency and voltage levels, ensuring further operation or resumption of operation of mechanisms of own needs;
- remove overloading dangerous for equipment and posing a threat of disturbance of stability of personnel-controlled links;
- provide synchronous and asynchronous reconnection of the divided parts at electric power stations and sub-stations by dispatcher's command or (in compliance with local dispatcher instructions) independently;
- provide synchronization of generators and electric power station disconnected during a failure in case of existence of voltage or its occurrence after the loss of it;
- if there is no voltage on electric power bus, keep generators in idle mode;
- if powerful power units cannot be kept in operation, ensure their readiness for rapid turning, reconnection to the network and gaining power;
- in cases specified by local dispatcher instructions, ensure rapid reconnection of important consumers to asynchronously operating generators;
- in case of voltage arising on buses after its complete loss, independently take measures for turning of mechanisms of own needs and generators and for synchronization with the network.

8. Power Reserves

The emergency reserve is provided within the entire energy system and is used within 10 minutes

Each wholesale market participant having generating sources shall provide:

- automatic rotation frequency controls (ARFC) on their units and power reserve required for their effective operation;

- emergency power reserve.

The necessary condition of electric power wholesale market operation is meeting the energy supply and electric power quality requirements. In this connection, the compulsory requirements for wholesale market participant could be defined as follows:

- maintenance of operating active power reserves (this requirement refers only to producers-suppliers of electric power on the wholesale market), required for maintenance of the set frequency level in the energy system;
- availability of reactive power reserves and control facilities required for maintaining the voltage level at control points of the main network of the energy system in heavy-duty and emergency operation modes.

Operating reserves and maintenance of operation in frequency and active power.

Maintenance of normal operation of the energy system requires availability of two main types of active power operating reserve:

- emergency (for prevention of dangerous decrease of frequency and its restoration to the normal level in chance failure of generating sources);
- regulating (to maintain the set frequency level in normal operation mode).

The main type of reserve to be provided by each wholesale market participant having generating sources is emergency reserve for compensation of possible failure of generating equipment.

Standards for Different Reserves in Long-Term Planning

Reserve	Purpose of reserve	Size
Consumer	Compensation of possible consumption increase, delay in introduction of new capacities	2-3% Pmax
Repair: for major and medium repair	Compensation of transfer or withdrawal of equipment for repair in year's maximum load period The same in the in the summer load fall	0.5-1% Pdist
	The same in maximum load period	Up to 9-10 % Pdist
for current repair	The same in other time	3-4% Pdist
	The same in any time	4-5 % Pdist
for emergency repair		4-5% Pdist

Reserves in Short-Term Planning (for a day and a week) and Operations Planning

Reserve	Purpose of reserve	Size of reserve	Type of reserve	Mobility of reserve
Repair (for emergency repair)	Compensation of withdrawal of equipment for emergency repair within short-term planning cycle	1-2 % Pdist	Hot (switched-on) Non-switched-on	Minutes Dozens of minutes -several hours
Load (regulating)	Reduction of load forecast error	1-2% Pmax	Switched-on Non-switched-on	Minutes Dozens of minutes -several hours
Emergency: category I	Stability disturbance prevention, automatic resumption of power supply to consumers disconnected by automatic failure prevention equipment, frequency restoration.	Depending on local conditions	Switched-on, mobilized by automatic equipment operation	Fractions of a seconds -dozens of seconds
category II	Liquidation of overload in current, restoration of normal stability margin, frequency restoration.	Depending on local conditions	Switched-on or non-switched-on, manually mobilize	Minutes-dozens of minutes
category III	Restoration of normal operation in significant power deficit	Depending on local conditions	Non-switched-on	Hours

9. Dispatcher Communication Facilities

9.1. Dispatcher Telephone Communication (DTC)

Dispatcher telephone communication shall be organized using two and more mutually reserved channels. Communication channels shall have a 2 KHz bandwidth and be connected to dispatcher switchboard at both ends.

Calls through DTC channels should be made using simple switching manipulations without dialing a number.

9.2. Facsimile Communication

Dispatcher Center should have facsimile communication facilities to transmit photo copies of printed and graphic documents.

9.3. Computer Communication

200-2400 bit/s production-technological communication switching channels can be used for computer communication.

9.4. Teleinformation Channels

Teleinformation channels may be duplex and simplex ones and are designed for operation at 50-2400 baud.

ATTACHMENT 2

HAGLER BAILLY MEMORANDUM DATED 20 AUGUST 1999, ENCLOSING DRAFT GRID CODE TO COUNTERPARTS

MEMORANDUM

TO: Georgia National Energy Regulatory Commission
Georgia Wholesale Electric Market
Sakenergo Dispatch

FROM: Hagler Bailly

DATE: 20 August 1999

SUBJECT: Draft Technical Standards

We enclose for your review and comment the Russian-language draft Technical Standards prepared by Hagler Bailly's Anatoly Lazebnik, whom some of you will recall met with representatives of your organizations in July. We will especially appreciate your comments on the following items.

- The draft assigns to the Dispatcher much responsibility for short and long-term planning. Some of these planning functions may properly be the responsibility of the Wholesale Market. You may, of course, assign these planning functions to whatever organization best meets the market's needs.

- The technical standards may be too demanding for the Georgia power system at present. We invite your attention, for example, to the provisions relating to system frequency. These should perhaps be modified to reflect actual system capabilities.

Hagler Bailly plans on having Mr. Lazebnik return to Georgia in the future to review and incorporate your comments on the draft. We will advise you of the dates of his visit when it is arranged.

Enclosure