Power System Resilience
(Draft)

Georgian State Electrosystem

GSE

Georgian Transmission Network 2010

Georgian Power System

- Georgian Transmission Network was designed for parallel operation with the North Caucasus and Armenia/Azerbaijan power systems. Hence 500 kV grid which had radial topology in territory of Georgia, was backed up by three neighbor countries simultaneously;
- Generation of the HPPs located in the West Georgia was transmitted to Russia, while the power plants located in the East Georgia were supplied with fuel from Azerbaijan;
- Starting from 90's, due to the independent reasons, there was no possibility of parallel synchronous operation with more than one neighboring country, which caused leaving internal radial network of Georgia as well as any operating interconnection line without backup.

Challenges of Georgian power system stability

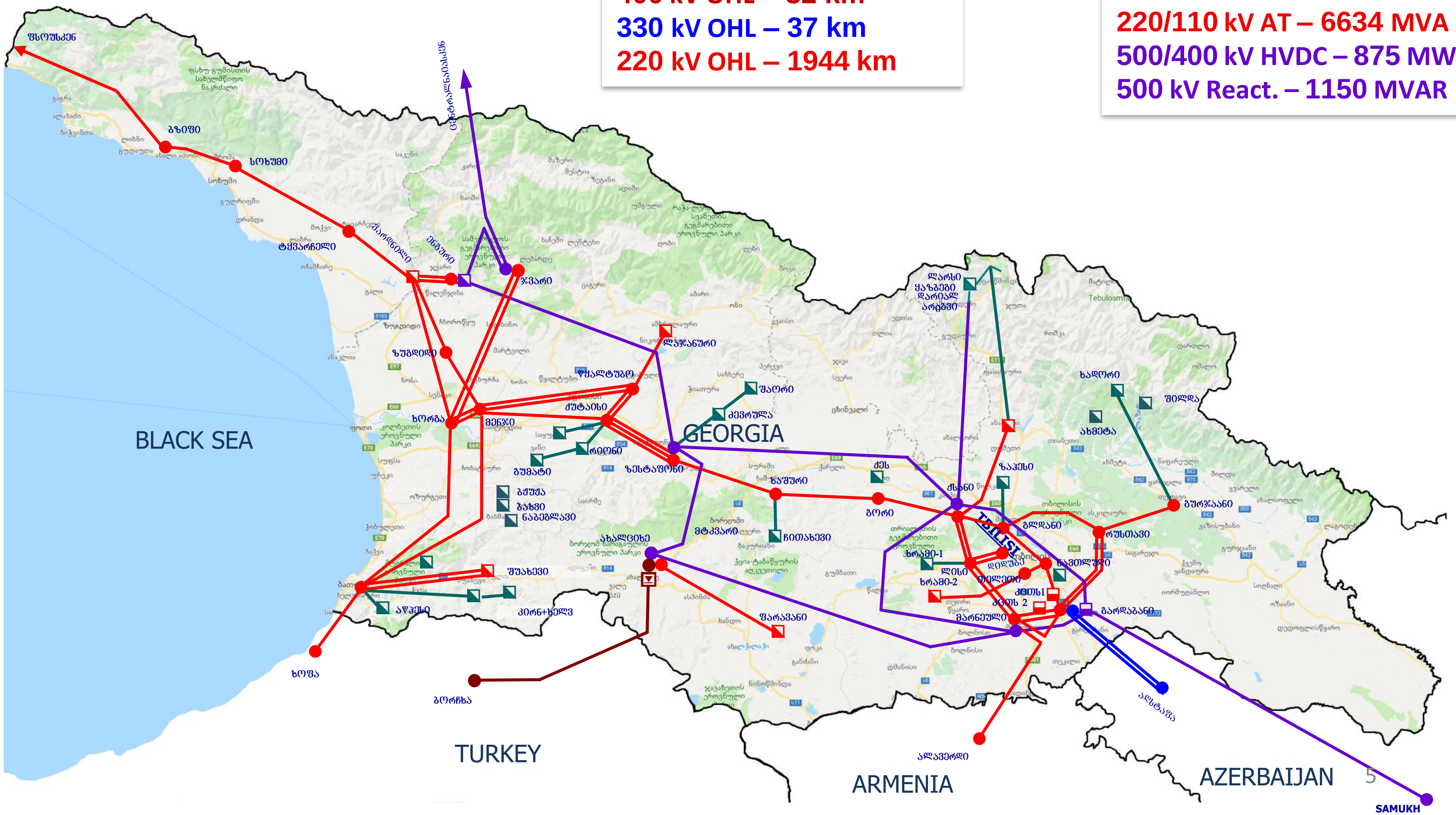
GSE

- Nowadays, parallel operating with only one neighbor country (either Russia, or Azerbaijan) and interconnection problems:
  - N-1 criteria with Russia;
  - Limited power flow with Azerbaijan.
- Lack of speed governors and low inertia phenomenon - due to the small size of Georgian power system (minimum load equals to 1,000 MW), outage of biggest generators (250 MW installed capacity) without RAS intervention can cause stability problems;
- Main generation objects located in the western part of Georgia and consumption – in the eastern. Their interconnector 500 kV backbone isn't fully reserved and N-1 criteria isn't fulfilled.

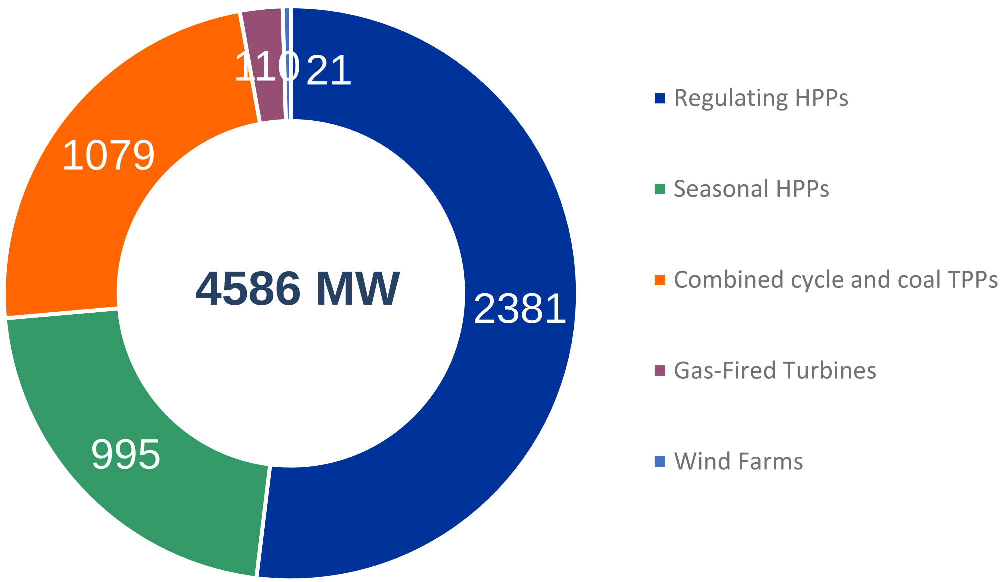
Existing Transmission Grid of Georgia

500 kV OHL – 935 km
400 kV OHL – 32 km
330 kV OHL – 37 km
220 kV OHL – 1944 km

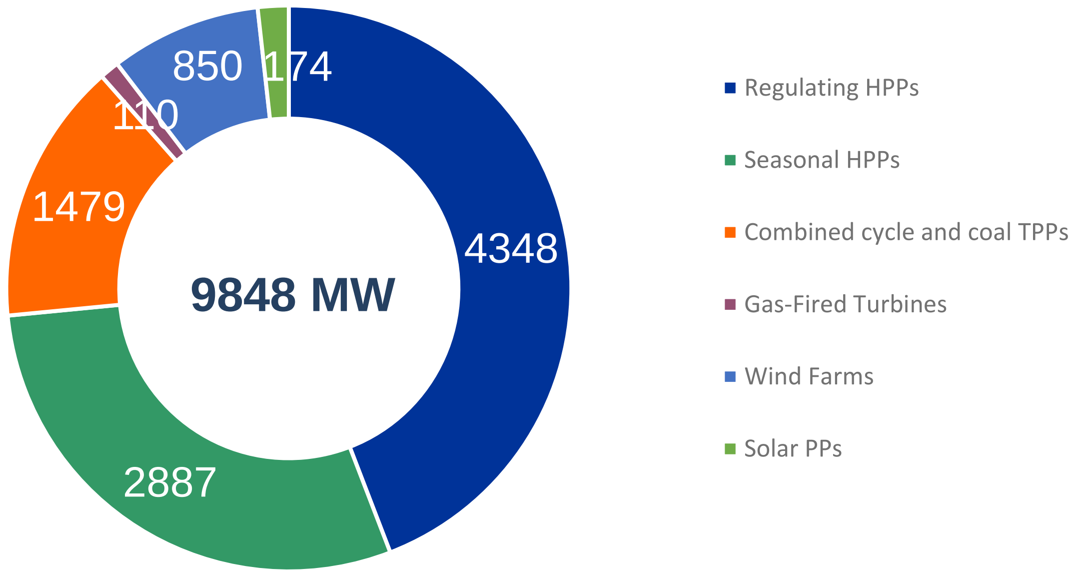
500/220 kV AT – 3960 MVA
330/220 kV AT – 400 MVA
220/110 kV AT – 6634 MVA
500/400 kV HVDC – 875 MW
500 kV React. – 1150 MVAR



Existing and Planned Installed Capacity of Generation Sources

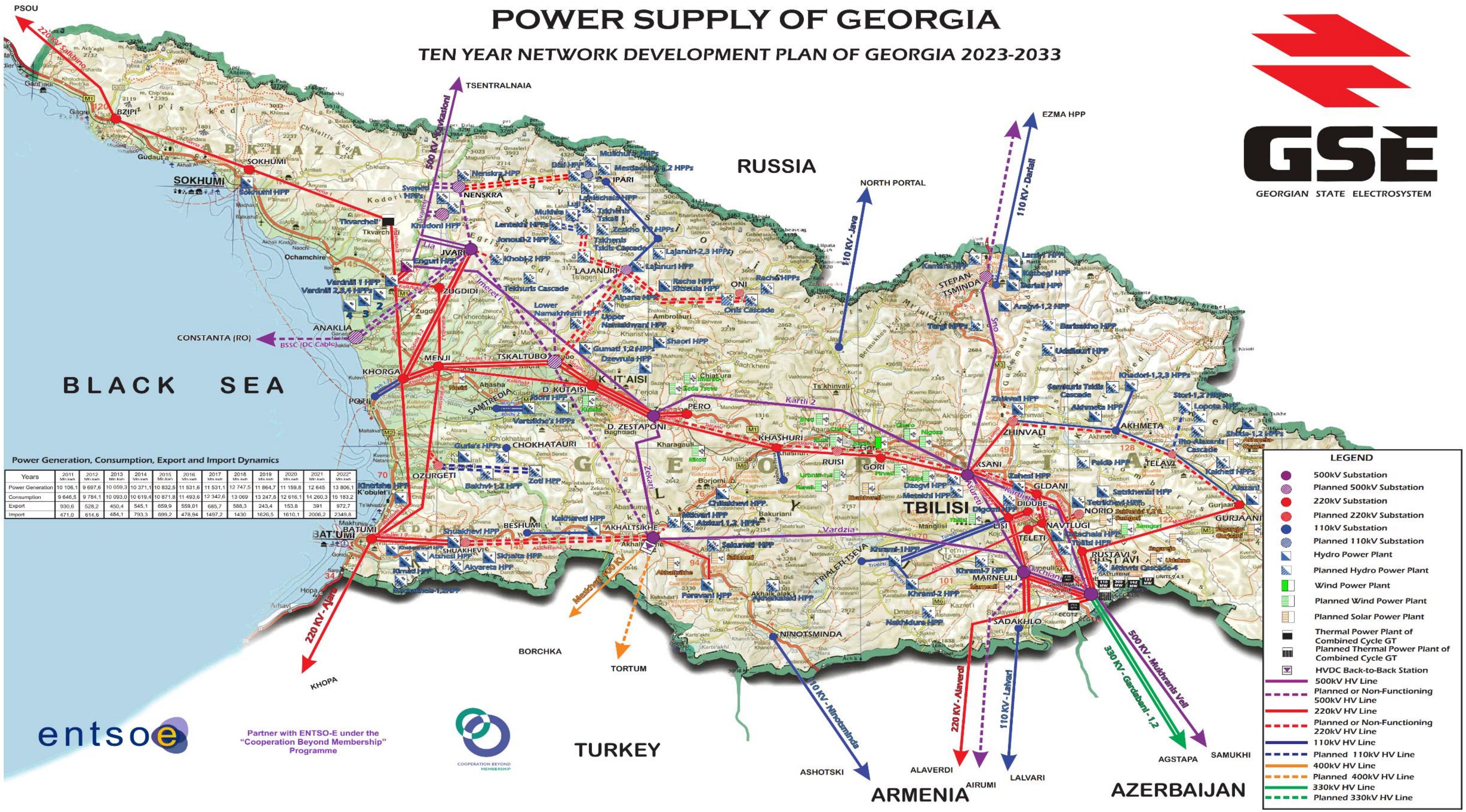


Installed capacities of the existing power plants



Installed capacities of power plants as for 2033

Georgian Transmission Network 2023-2033



Power Generation, Consumption, Export and Import Dynamics

Years	2011 Mln.kwh	2012 Mln.kwh	2013 Mln.kwh	2014 Mln.kwh	2015 Mln.kwh	2016 Mln.kwh	2017 Mln.kwh	2018 Mln.kwh	2019 Mln.kwh	2020 Mln.kwh	2021 Mln.kwh	2022* Mln.kwh
Power Generation	10 106,1	9 697,6	10 059,3	10 371,1	10 832,5	11 531,6	11 531,1	12 747,5	11 864,7	11 159,8	12 645	13 806,1
Consumption	9 646,5	9 784,1	10 093,0	10 619,4	10 871,8	11 493,6	12 342,6	13 069	13 247,8	12 616,1	14 260,3	15 183,2
Export	930,6	528,2	450,4	545,1	659,9	559,01	685,7	588,3	243,4	153,8	391	972,7
Import	471,0	614,6	484,1	793,3	699,2	478,94	1497,2	1430	1626,5	1610,1	2006,2	2349,8

Power System Resilience

Power system resilience is the ability to limit the extent, severity, and duration of system degradation following an extreme event

A summary of the main risks to be addressed are:

- Extreme natural events, such as earthquakes, hurricanes, floods, wildfires, tsunamis
- Cyber and physical security vulnerability, including Electromagnetic Pulse (EMP)
- Inadequate system state awareness
- Changing resource mix
- Bulk power system planning, adequacy and performance
- Lack of skilled workforce

Power system resilience

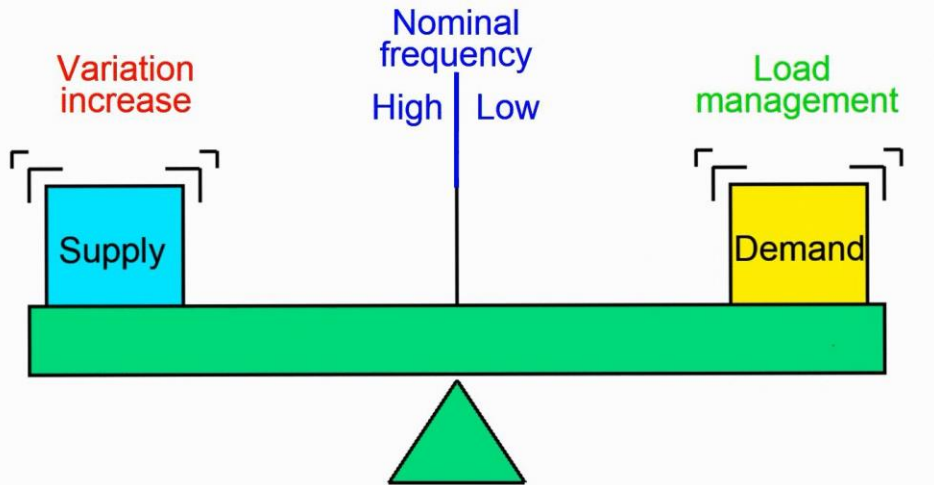
Power system resilience is achieved through a set of key actionable measures to be taken before, during, and after extreme events, such as:

- Anticipation;
- Preparation;
- Absorption;
- Sustainment of critical system operations;
- Rapid recovery;
- Adaptation;
- Application of lessons learnt.

Operational resilience

In power system operations, resilience generally means the ability to respond quickly to and recover from a disruption.

- In Emergency Situations Action Plan Provides:
  - Automatic and manual load shedding
  - Triggering of Remedial Action Schemes (RAS) complex
  - Manage constraints in synchronous state
  - Restoration of supply



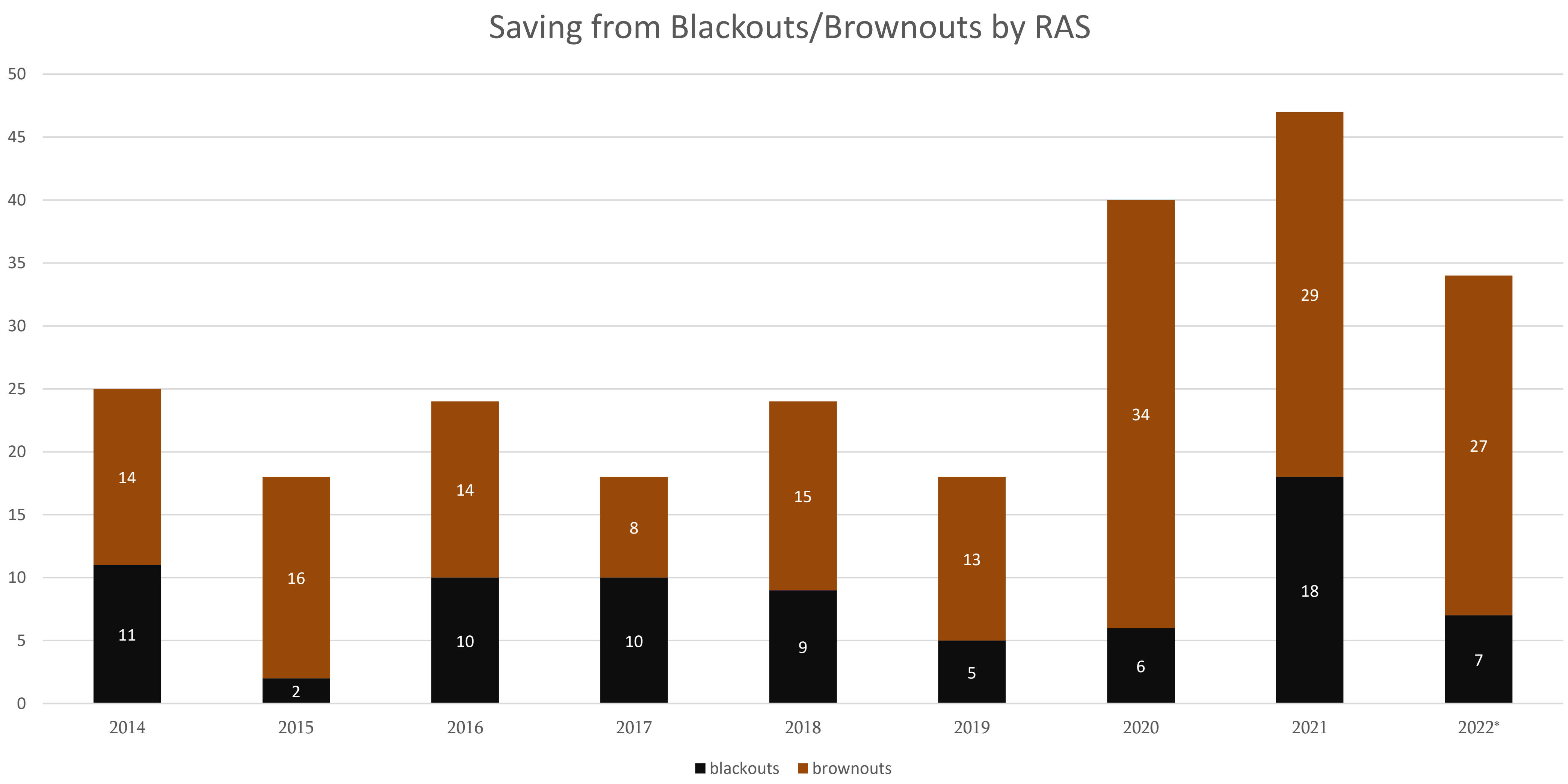
Remedial Action Schemes (RAS)

- The RAS devices maintain static, dynamic and resultant stability of the power system. They respond in both cases, when the network is operating in steady mode, or when one of the transmission lines is under maintenance outage;

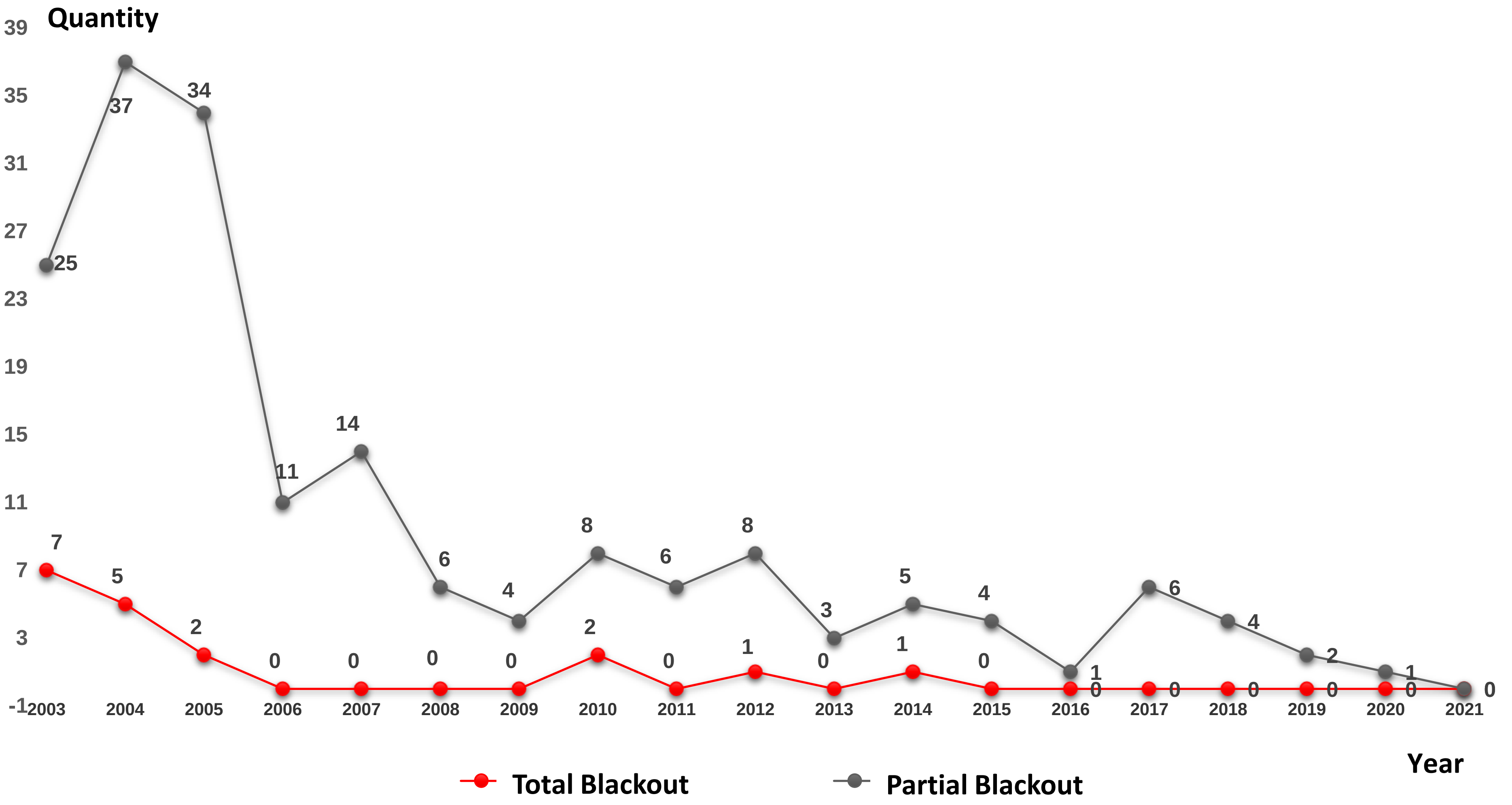
- RAS devices continuously monitor the status and operating regimes of the system elements, identify and record hazardous events or abrupt violation of the normal regimes, assess their severity and, in case of emergencies, send signals to the logic processor that compares sequence and intensity of the signal and selects the relevant response command (generation reduction, load shedding or both);

- Under the single contingency (N-1), in case of active power excess in the system, RAS will initiate rapid automatic reduction of the active power generation in Enguri HPP, while in case of active power shortage, will shed the load (in the country) and, if needed, the export (re-export).

Annual statistics of saving from Blackouts & Brownouts by RAS



Blackout Statistics 2003-2021

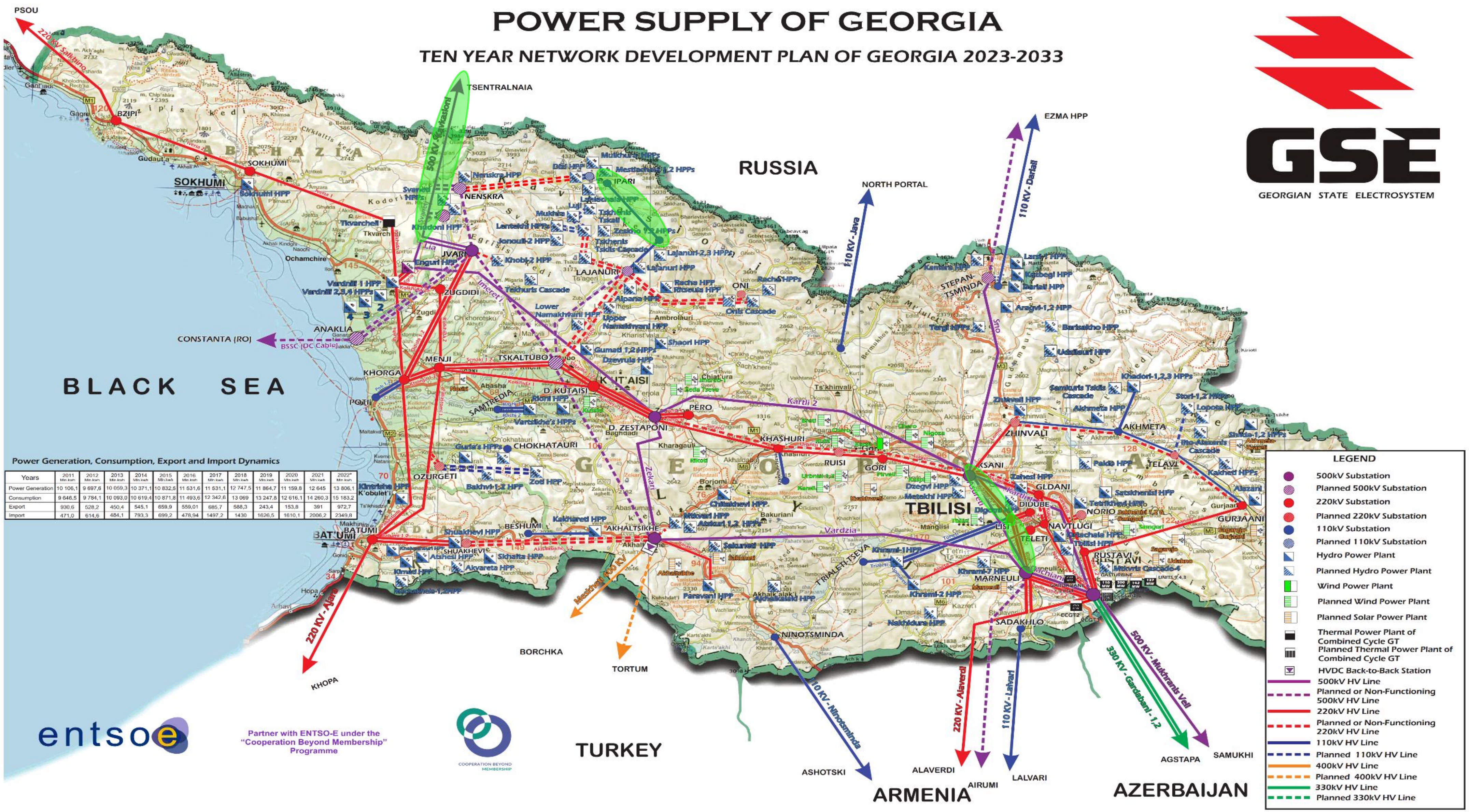


Black Start Program and Emergency Trainings

- Black-start program has been elaborated in GSE in 2015. This program included list of the existing power plants capable of black-start service.

- Emergency trainings for operational staff of Dispatchers of National Control Center (NCC) are performed in simulation exercises to check the level of training of dispatchers and to study the methods of restoration of the power system in case of emergency situations. Emergency trainings are carries out on a quarter basis.

Georgian Transmission Network 2023-2033



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Damaged Infrastructure of 500 kV OHL Kavkasioni

Damaged towers 110 kV OHL Ifari

2018

2019

2021

Ice Cover on 220 kV OHL Didgori – 1,2

Damaged Towers and Insulators of 220 kV OHL Koda 1,2 caused by heavy Hail and Hurricane

Technological Disruption in SCADA System in 2021

GSE

Out of ordering of cooling system of server caused increase of temperature in server rooms above their critical range. As a result, access of IT and SCADA users to control and monitoring software Spectrum has been totally terminated. Mentioned incident put GSE's critical importance main and backup infrastructure under the risk, which itself could cause negative results which much higher scale in whole electro system.

According to the conclusion of data center audit, emergency outage of "precision conditioner" installed in the server rooms in substation "Navtlughi-220" has been result of "High Pressure" flaw. Second conditioner was not able to sufficiently cool server rooms, due to which room temperature has been increased up to 45°C critical level. Based on above-mentioned, process development was the reason of starting emergency mode of the servers and total shutdown of their part after specific period. Reserve dispatch center of SCADA system remained in operation. However, access to Spectrum software for SCADA system users has been terminated during elimination of mentioned technological disruption (30-40 minutes).

Taken and Planned Measures

GSE

- ✓ Procurement of technical support for UPS and cooling system located in server facilities has been implemented. Fault caused by incident has been eliminated in framework of the contract and monitoring and technical service of UPS and cooling system is done on a regular basis
- ✓ Respective instruction has been elaborated by SCADA and IT department administrators in order to implement necessary measures with respective consequence in case of similar incidents in order for their elimination
- ➢ In order to ensure uninterrupted operation of IT services, including telephone system, the project of procurement of high-performance servers and network equipment compatible to the modern technologies and of introduction of scheme of uninterrupted operation (active – active) of data centers in ongoing
- ➢ For the purpose of arrangement of alarm system for server infrastructure temperature monitoring and critical temperature, arrangement of reserve independent SMS system is planned

Electricity Crisis Scenarios

Identification and Evaluation of the Electricity Crisis Scenarios

- On December 2, 2020 was approved the Security of Electricity Supply rules;
- Regarding the Annex 1 of the SoS rules TSO has to identify relevant electricity crisis scenarios for Georgia in close cooperation with the Ministry of Economy and Sustainable Development of Georgia;
- According to the SoS rule GSE is also preparing Risk-Preparedness plan, that is under development.

Identification of electricity crisis scenarios → **Evaluate scenarios** → **Ranking of scenarios**

Identification of electricity crisis scenarios:

1. Identification of scenario
2. Cross-border dependencies
3. Description of scenario
4. Submission of scenario

Evaluate scenarios:

1. Assessment of impact
2. Description of impact

Ranking of scenarios:

1. Ranking of all scenarios

Electricity Crisis Scenarios

GSE

1 Summer congestion
2 Winter tension
3 Interruption of SCADA

Evaluation of scenarios

Steps

1. Determine likelihood of scenario
   - Identify class of likelihood

Crisis Likelihood Scale

For classification of likelihood of crisis, a five-step scale is used:

Classification	Events per year	1 x in ... years	Description/example of initiating event
Very likely	≥ 0.5	2 or less	event expected practically every year, e.g. extreme winds/storms causing multiple failures of overhead lines may be expected nearly every year in some areas
Likely 1	0.2-0.5	2-5	event expected once in a couple of years, e.g. extreme heat wave causing limits on output of open-loop water-cooled power plants, low water levels at hydro plants, higher load, etc.
Possible 2	0.1-0.2	5-10	event expected or taken into consideration as a potential threat, e.g. cyber or malicious attack
Unlikely 3	0.01-0.1	10-100	very rare event with potentially huge impact, e.g. simultaneous floods causing unavailability of generation, distribution and transmission infrastructure
Very unlikely	≤ 0.01	100 or more	event not observed but potentially disastrous, e.g. earthquake causing a huge destruction of transmission, distribution and generation infrastructure

2. Determine impact of scenario
   - Identify class of impact :
     - By use of risk indicators: EENS, LOLE

Crisis Impact Scale

Classification	EENS% (of annual demand)	LOLE [hours]
Disastrous	≥0,25%	≥168
Critical 2 3	≥0,05% and <0,25%	≥48 and <168 2 3
Major	≥0,01% and <0,05%	≥12 and <48 1
Minor 1	≥0,002% and <0,01%	≥3 and <12
Insignificant	<0,002%	<3

Electricity Crisis Scenarios

Evaluation of scenarios

Steps

1 Summer congestion
2 Winter tension
3 Interruption of SCADA

Scenario	Likelihood	EENS%	LOLE
1	Likely	Minor	Major
2	Possible	Critical	Critical
3	Unlikely	Critical	Critical

Support for the numbers:

- Likely: 1 every 2-5yrs → 20-50% probability
- Possible: … 5-10yrs → 10-20% probability
- Unlikely: …10-100yrs → 1-20% probability

Impact		Likelihood				
EENS%	LOLE	Very likely	Likely	Possible	Unlikely	Very unlikely
Disastrous	Disastrous	Disastrous	Disastrous	Critical	Major	Minor
Disastrous	Critical	Disastrous	Critical	Critical	Major	Minor
Critical	Disastrous	Disastrous	Critical	Critical	Major	Minor
Disastrous	Major	Disastrous	Critical	Major	Major	Minor
Major	Disastrous	Disastrous	Critical	Major	Major	Minor
Disastrous	Minor	Disastrous	Critical	Major	Major	Minor
Minor	Disastrous	Disastrous	Critical	Major	Major	Minor
Disastrous	Insignificant	Disastrous	Critical	Major	Major	Minor
Insignificant	Disastrous	Disastrous	Critical	Major	Major	Minor
Critical	Critical	Disastrous	Critical	M 2	Mi 3	Minor
Critical	Major	Critical	Critical	Major	Minor	Minor
Major	Critical	Critical	Critical	Major	Minor	Minor
Critical	Minor	Critical	Major	Major	Minor	Minor
Minor	Critical	Critical	Major	Major	Minor	Minor
Critical	Insignificant	Critical	Major	Major	Minor	Minor
Insignificant	Critical	Critical	Major	Major	Minor	Minor
Major	Major	Critical	Major	Major	Minor	Insignificant
Major	Minor	Major	Major	Minor	Minor	Insignificant
Minor	Major	Major	M 1	Minor	Minor	Insignificant
Major	Insignificant	Major	Major	Minor	Minor	Insignificant
Insignificant	Major	Major	Major	Minor	Minor	Insignificant
Minor	Minor	Major	Minor	Minor	Insignificant	Insignificant
Minor	Insignificant	Major	Minor	Minor	Insignificant	Insignificant
Insignificant	Minor	Major	Minor	Minor	Insignificant	Insignificant
Insignificant	Insignificant	Minor	Minor	Insignificant	Insignificant	Insignificant

Thank You Very Much!

Giorgi Amuzashvili

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