TURKISH POWER SYSTEM

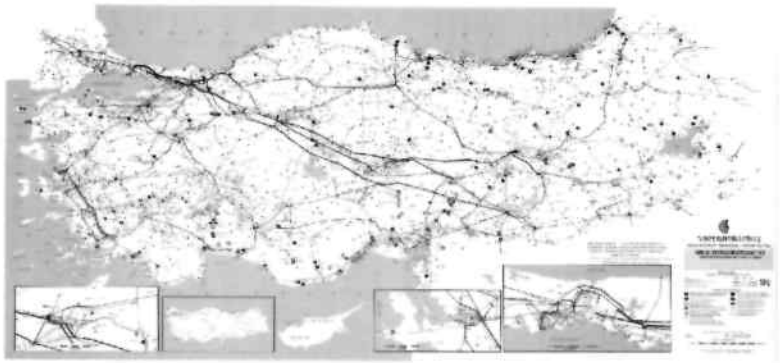
MAIN RESPONSIBILITIES of TEIAS

- The sole owner of Electricity Transmission System
- Responsible for the expansion of transmission network infrastructure & construction of new transmission facilities
- Operating & Maintaining the Turkish Electricity Transmission Network in economic and reliable manner, in compliance with international standards
- Monitoring real-time system reliability, purchasing Ancillary Services
- Preparing Generation Capacity Projection
- Developing international connections

TURKISH ELECTRICITY TRANSMISSION COMPANY

TEİAŞ

GRID MAP



SUBSTATIONS

400 kV : 97
220 kV : 1
154 kV : 584
66 kV : 13
Total : 695 Subs.
with 133.744 MVA capacity

TRANSMISSION LINES

400 kV : 18.484,4 km
154 kV : 37.579,0 km
220 kV : 84,5 km
66 kV : 509,4 km
154 & 400 kV Cable: 337,7 km
Total : 56.995 km

TURKISH ELECTRICITY TRANSMISSION COMPANY

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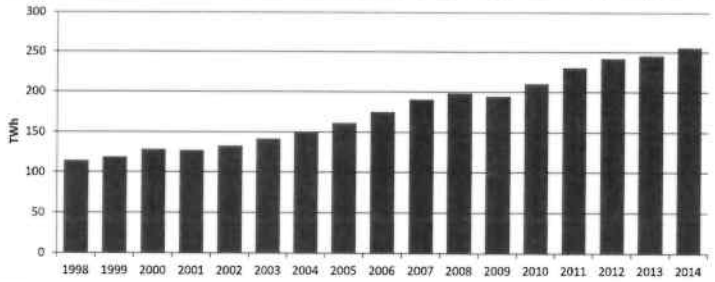
ENERGY CONSUMPTION

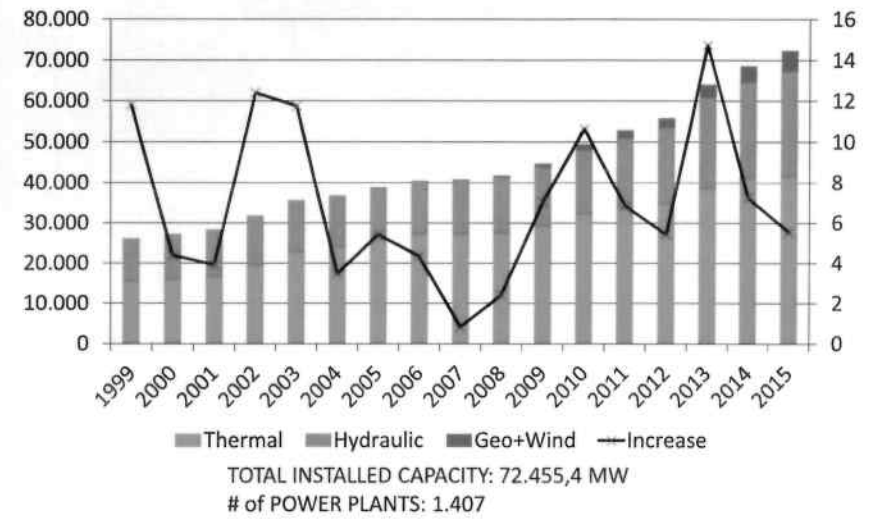
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CONSUMPTION (TWh)	114,0	118,5	128,3	126,9	132,6	141,2	150,0	160,8	174,6	190,0	198,1	194,1	210,4	230,3	242,3	246,3	257,2
INCREASE (%)	8,1	3,9	8,3	-1,1	4,5	6,5	6,3	7,2	8,6	8,8	4,3	-2,0	8,4	9,4	5,2	1,6	4,4



TURKISH ELECTRICITY TRANSMISSION COMPANY

TEİAŞ

INSTALLED CAPACITY



TOTAL INSTALLED CAPACITY: 72.455,4 MW

# of POWER PLANTS: 1.407

TURKISH ELECTRICITY TRANSMISSION COMPANY

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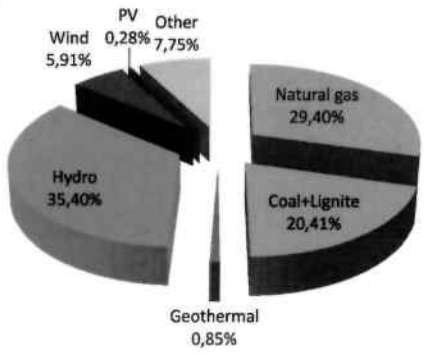
INSTALLED CAPACITY BY PRIMARY SOURCE (October 2015)

Installed Capacity	72.455,4 MW
Natural Gas	21.304,7
Coal+Lignite	14.787,5
Geothermal	614,2
Hydro	25.648,7
Wind	4.280,7
PV	203,1
Other	5.616,5



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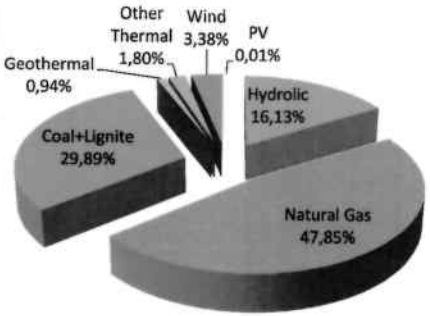
PRODUCED ENERGY by PRIMARY SOURCES (2014)

Total	251.962,8 TWh
Natural Gas	120.576,0
Coal+Lignite	75.308,5
Geothermal	2.364,0
Hydro	40.644,7
Wind	8.520,1
PV	17,4
Others	4.532,1



TURKISH ELECTRICITY TRANSMISSION COMPANY

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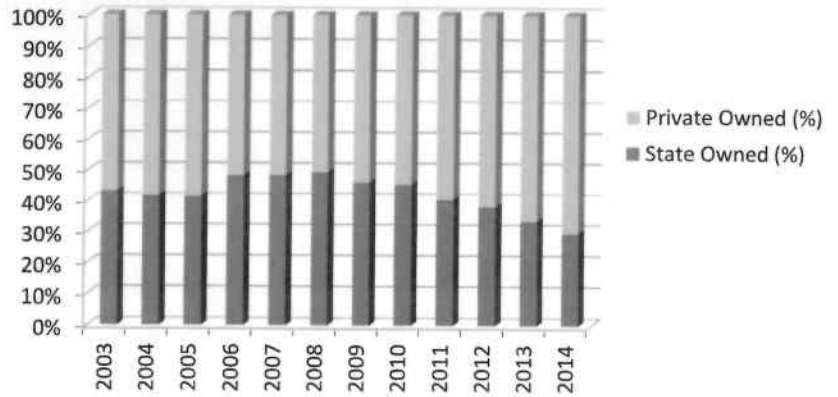
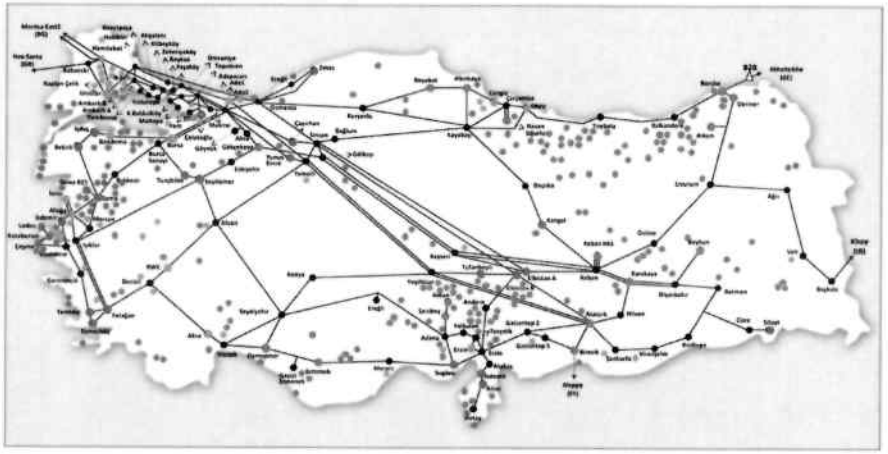
OWNERSHIP IN GENERATION



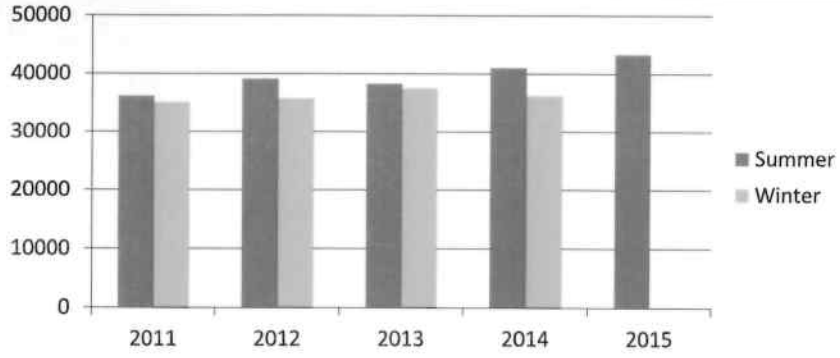
LOCATION OF THE PPS



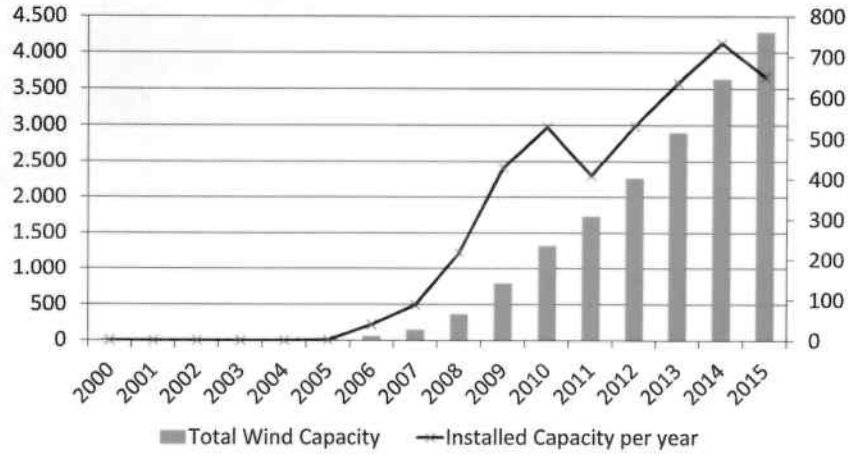
- Coal-Fired Power Plants
- Natural Gas Plants
- Wind Power Plants
- Hydro Power Plants

PEAK LOAD & TRANSMISSION LOSSES

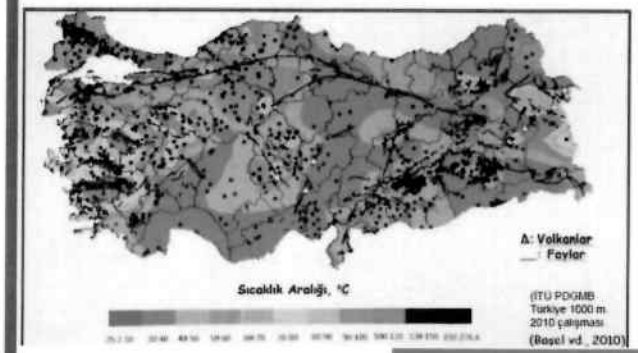
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
(%)	3.26	2.95	2.84	2.85	2.88	2.68	2.48	2.26	2.82	2.40	2.25	2.27	2.67



WIND ENERGY DEVELOPMENT



GEOTHERMALS



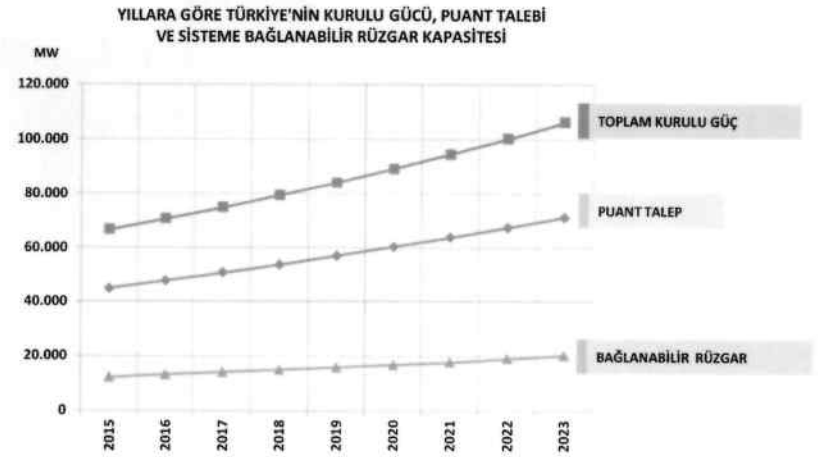
31.10.2015	
Installed Capacity	614,2 MW
Licences given	137,3 MW
Pre-licence given	451,3 MW
Total	1202,8 MW

RES TARGETS

According to Ministries Stragegy Paper:

- Using All economic HPP potential (135 billion kWh)
- Reaching 20.000 MW Wind installed Capacity
- Reaching at least 3.000 MW PV installed capacity
- Reaching at least 600 MW Geothermal installed capacity
- Bio-mass 1.500 MW

CAPACITY PROJECTION



TURKISH ELECTRICITY TRANSMISSION COMPANY

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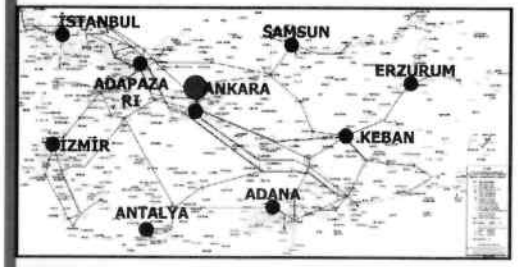
OPERATION OF THE POWER SYSTEM



- 1 NCC
- 9 RCC
- 22 Regional Center in charge of Maintenance&Investments

TURKISH ELECTRICITY TRANSMISSION COMPANY

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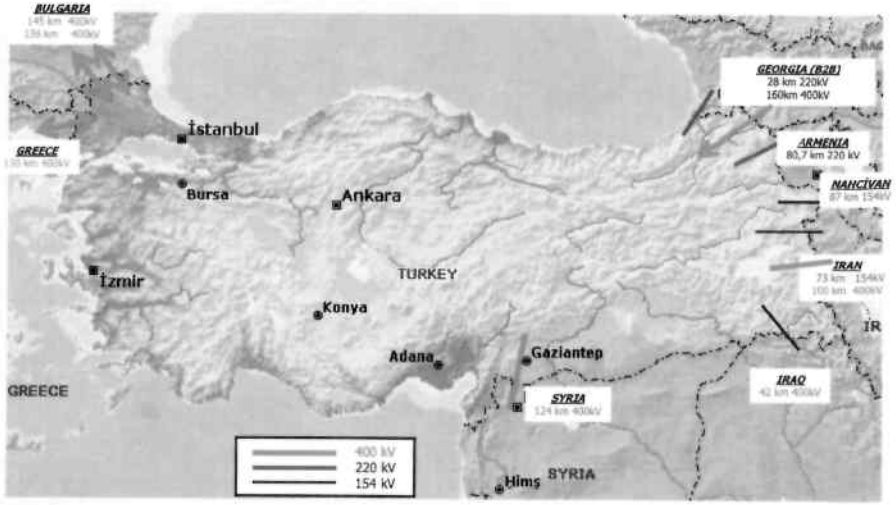
EXISTING INTERCONNECTIONS



TURKISH ELECTRICITY TRANSMISSION COMPANY

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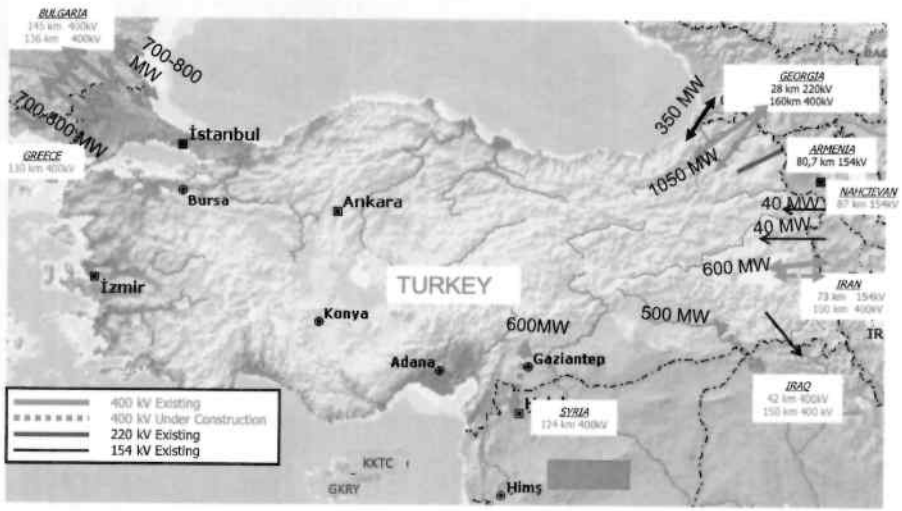
PLANNED INTERCONNECTIONS



TURKISH ELECTRICITY TRANSMISSION COMPANY

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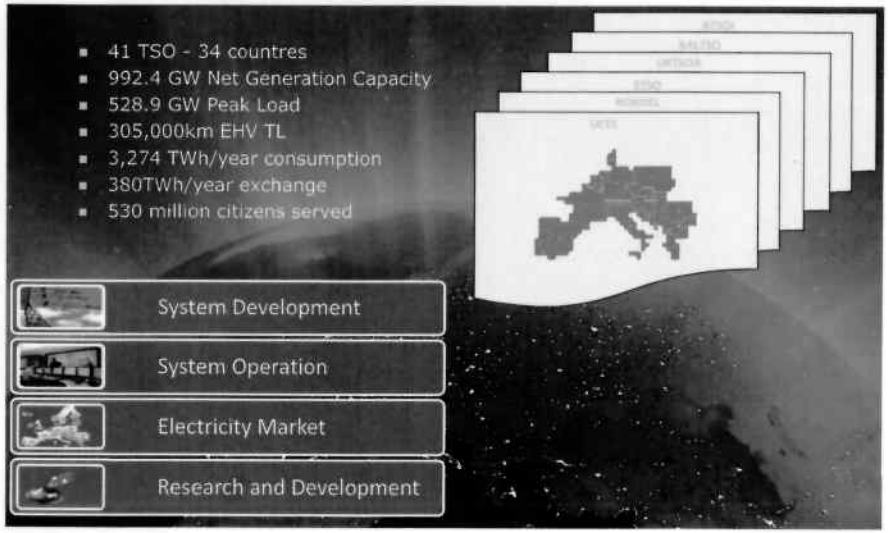
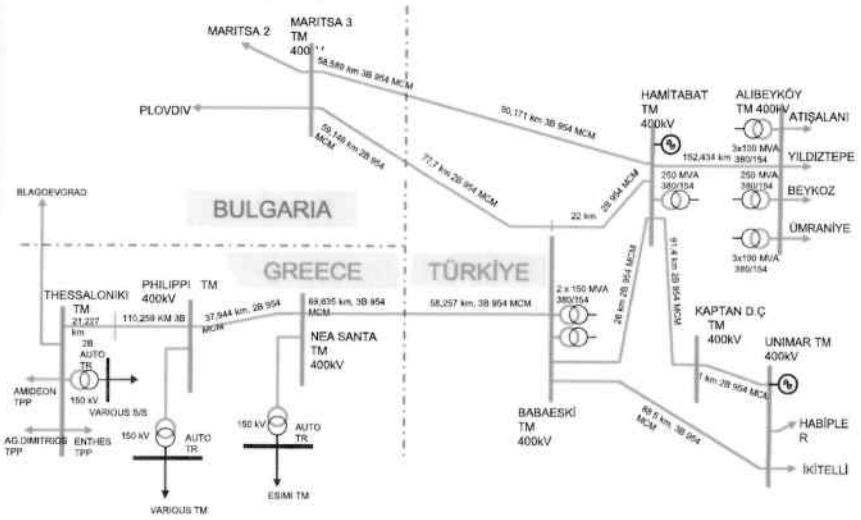
TEIAS-ENTSO-E CONNECTION

WHO IS ENTSO-E?

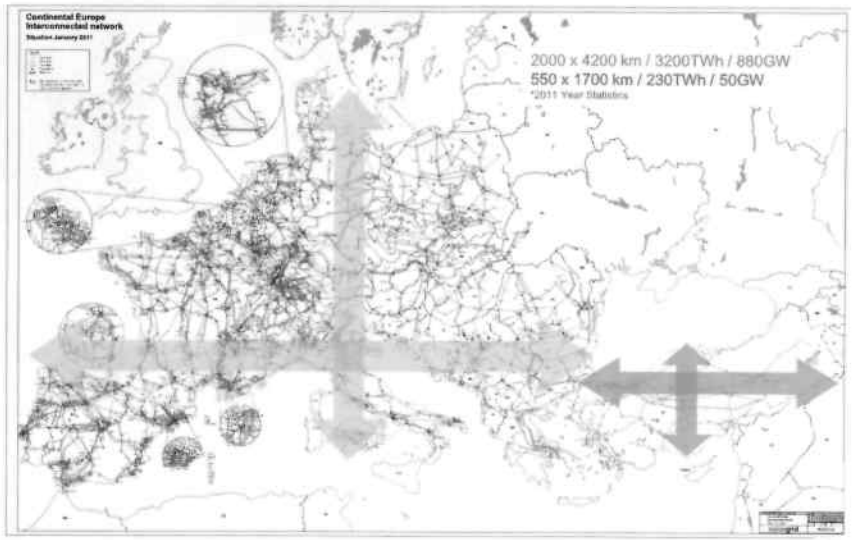
- 41 TSO - 34 countres
- 992.4 GW Net Generation Capacity
- 528.9 GW Peak Load
- 305,000km EHV TL
- 3,274 TWh/year consumption
- 380TWh/year exchange
- 530 million citizens served



TURKEY-ENTSO-E INTERFACE



A REAL CHALLENGE



OBJECTIVE

- Get benefit of synchronous parallel operation
- Integration of the "Turkish Electricity Market" with "Internal Electricity Market" of EU

ADVANTAGES OF SYNCHRONOUS PARALLEL OPERATION

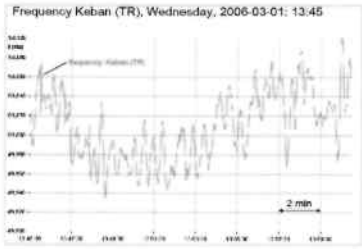
Technical
- Security of supply
- Increasing the quality of electricity

Economical
- Decreasing hot and cold reserves
- Decreasing the need for installed capacity -> postponing the investments
- Developing electricity trade

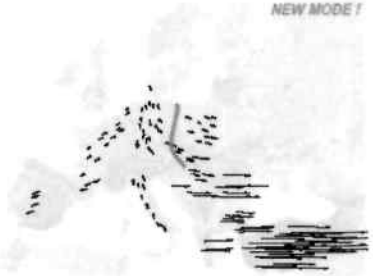
Other
- Protecting the environment
- ....

TECHNICAL CHALLENGES

- Frequency control quality improvement
- Risk of inter area oscillations
- Measures against propogation of disturbances



NEW MODE !



BACKGROUND

2000

Application

entsoe

PPC (GR)

UCTE Steering Committee

Consider all possibilities of synchronous connection

UCTE System Development Working Group

"Turkey's Connection" Sub-Group

- -TOR
- Tests
- Reports
- Agreements

PROJECT-1

"Complementary Studies for the Synchronisation of Turkish Power System with UCTE System"

Budget : 1.5 Million €
EC through the programme of Pre-accession Financial Assistance for Turkey as a 2003 Programme

RWE · ΔΕΣΜΗΕ · e·on Netz · RTE · HEP · NEK

CONCLUSIONS FROM PROJECT-1

- The system interconnection of Turkey to UCTE is **feasible** under following conditions:
  - the existing inherent frequency control problem is resolved
  - positive damping effect of AVR for the 0,15 Hz inter-area oscillations is assured in the majority of generation units
- A Special Protection Scheme at the interface is necessary to manage extreme contingencies
- The power transfer from Turkey to UCTE must not exceed 500MW during the trial operation

PROJECT-2

"Rehabilitation of the Frequency Control Performance of Turkish Power System for Synchronous Operation with UCTE"

Budget: 2.5 Million€

Implementation of the measures defined in 1. Project

Turkish Power System is prepared for future parallel operation with UCTE

Members of the consortium

Subcontractors

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GOVERNOR OPTIMIZATION

						Rehabilitation or Retuning		
HPP Name	Units	Rated Power [MVA]	T_W [s]	Objective Modification	Operational Importance	*Short Term (2009-2010)*	*Long Term*	*Onsite tuning*
Atatürk	8x315	2520	2,7...3,95	*	Base Load	Rehabilitation		completed
Karakaya	6x315	1890	1,06...1,24	*	Base Load	Rehabilitation		completed
Birecik	6x140	840	2,17	*	Base Load	Retuning		completed
Keban	4x175	700	2,35...2,46	*	Base Load	Retuning	Rehabilitation	high dead-band
	4x201	804	2,37...2,46	*	Base Load	Retuning	Rehabilitation	Same as first 4 units
Altinkaya	4x195	780	0,92	*	Base Load	Retuning	Rehabilitation	completed
Oymapinar	4x150	600	0,79	*	Peak Load	Rehabilitation		completed
Berke	3x187	561	0,41	*	Peak Load	Retuning		completed
Hasan Ugurlu	4x145	580	1,52	*	Base Load	Retuning		completed
Sir	3x105	315	0,35	**	Peak Load	Retuning		completed
Gokcekaya	3x105	315	-	*	Peak Load	Retuning	Rehabilitation	Same as Keban
Borcka	2x167	334	1-1,2	**	Peak Load	Retuning		completed
TOTAL		10239						

Priority

* Island Mode Stability

** Primary Control activation (30s-ramp)

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AVR & PSS TUNING

Power Plant	Type	Power / MVA	Onsite tuning	Comments
Atatürk	HPP	8x315	completed	ABB+JTS
Karakaya	HPP	6x315	completed	ABB+JTS
Unimar	CC	2x210 & 1x212	completed	Alsthom
Temelli	CC	2x309 & 1x380	completed	GE+Alsthom
Adapazari	CC	2x306 & 1x332	completed	GE+Alsthom
Aliaga	CC	4x306 & 2x332	completed	GE+Alsthom
Gebze	CC	4x306 & 2x332	completed	GE+Alsthom
Elbistan B	TPP	4x403	completed	Mitsubishi+JTS
Isken	TPP	2x660	1st site workV 2nd one ASAP	Siemens USA
Oymapinar	HPP	4x150	completed	Vatech+JTS

TOTAL ~ 14000 MW

SPECIAL PROTECTION SYSTEM

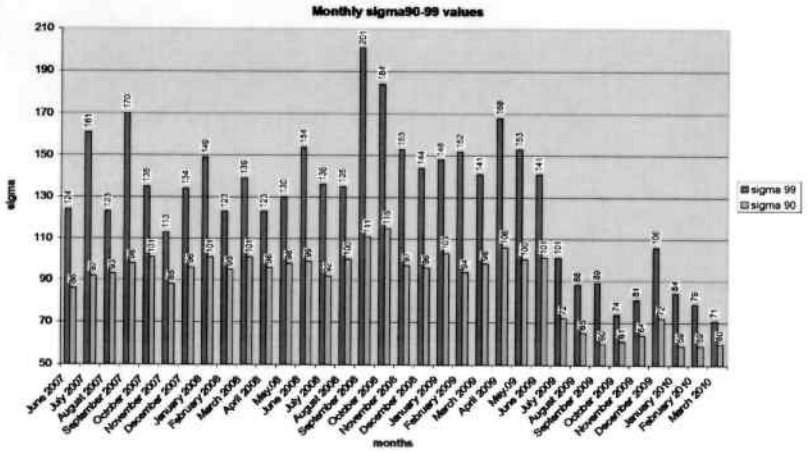
OBJECTIVE

- to prevent the propogation of the disturbance to ENTSO-E in case of extreme contingency in Turkish EPS (Big Load or generation trip)
- to keep working in synhronous mode with ENTSO-E as long as possible
- to make sure load flow on interconnections within limits
- to prevent Turkish EPS disconnect from ENTSO-E due to angular or voltage instabilitiy by load schedding or generation tripping

SUMMARY OF THE ACTIVITIES

- Survey of the power plants
- Design of governor control&parameter optimization
- Secondary Control optimization
- Training
- 10240 MW Hydro Rehabilitated or retuned
- 8 TPP Rehabilitated
- 14000 MW AVR&PSS retuned
- Modifying SVC (±1150 MVAR)
- Installation of STATCOM (±50 MVAR)
- Installation of Special Protection System

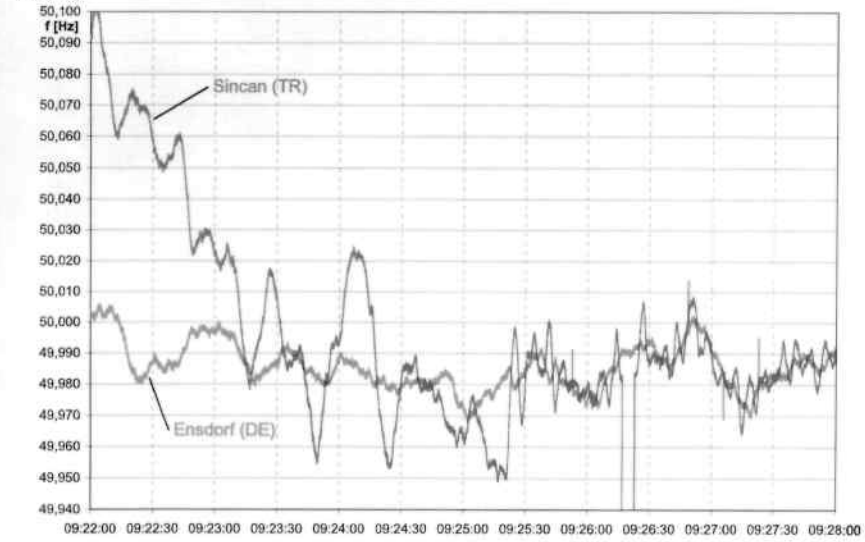
FREQUENCY IMPROVEMENT



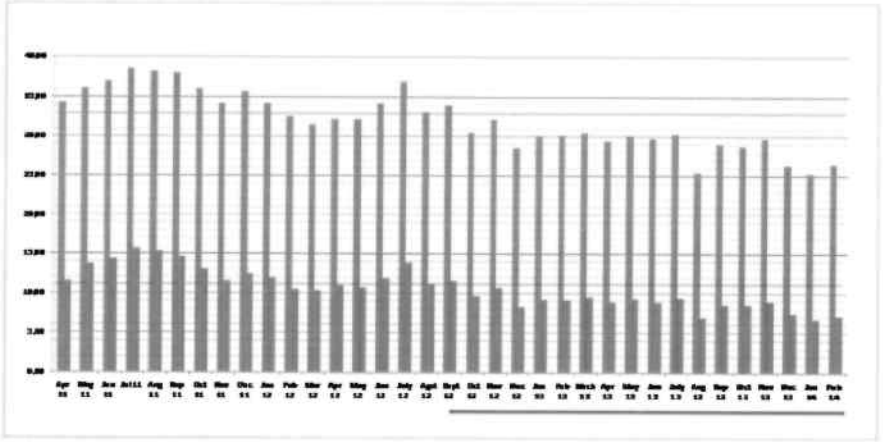
ISOLATED TESTS

Trumpet curve (envelope curve), January 13, 2010 15:04:50 h
tripping of generation in TR - 599 MW

SYNCHRONIZATION



SUCCESFUL OPERATION OF TEIAS



MILESTONES

Milestone	Date
Complementary Studies for the Synchronisation of Turkish Power System with UCTE System	2005 –2007
Rehabilitation of the Frequency Control Performance of Turkish Power System for Synchronous Operation with UCTE	2007 - 2009
Contractual Agreement between ENTSO-E & TEİAŞ	18 December 2009
Isolated Operation Test (Peak Load)	11-24 January 2010
Isolated Operation Test (Min. Load)	22 March-5 April 2010
Synchronisation and Synchronous Parallel Operation Test Phase 1	18 September 2010
Synchronous Parallel Operation Test Phase 2	21 Feb.-7 March 2011
Synchronous Parallel Operation Test Phase 3	1 June 2011 -
Increase of NTCs	17 April 2013
Decision for Permanent Synchronous Operation	9 & 24 April 2014
Signing of the Long Term Agreement	15th April 2015

BENEFITS

- More stable frquency -> more stable network
- Reducton of Primary reserve around 500 MW
- Cross-border trade
- Integration of the "Turkish Electricity Market" with "Internal Electricity Market" of EU

CROSS-BORDER TRADE

TURKISH ELECTRICITY
TRANSMISSION COMPANY
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CROSS-BORDER TRADE

- TCAT Platform for TR-BG border
- Monthly auctions
  - Daily and Yearly in 2016
- SEE CAO for TR-GR border
  - Yearly, Monthly and Daily auctions
- Yearly auctions for non-synchronous borders
- Explicit auctions
- TCAT Platform
  - Auction
    - Auction Announcements
    - Auction Results
  - Secondary Market
  - Counterparty Notification
  - Nomination
  - Auction Rules, other documents
  - Registered Users List
  - Announcements
  - Maintenance Periods
  - Curtailments
  - Contact Information
  - Turkish/English
- https://tcat.teias.gov.tr/

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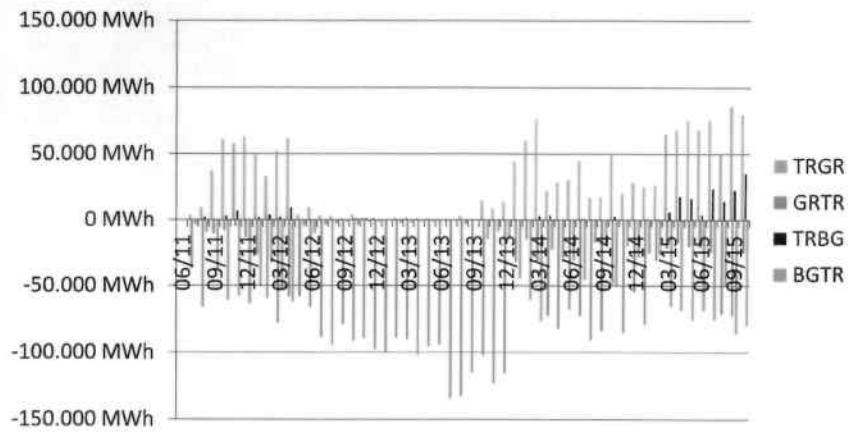
COMMERCIAL FLOWS



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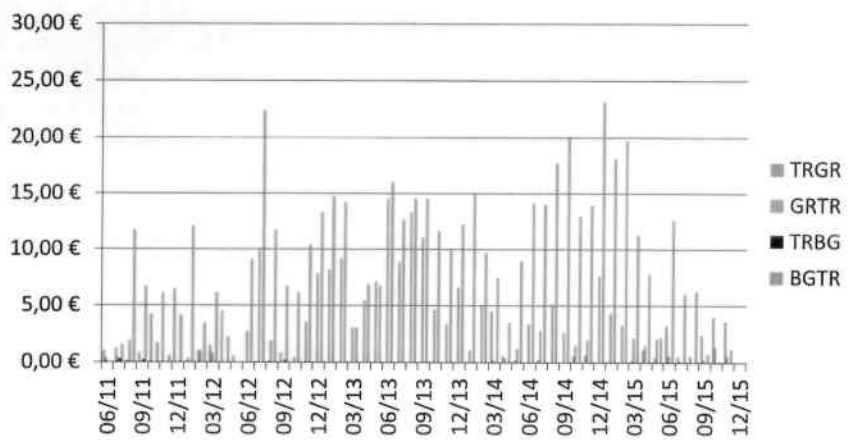
MONTHLY AUCTION PRICES



SOUTH EAST EUROPE COORDINATED AUCTION OFFICE (SEE CAO)

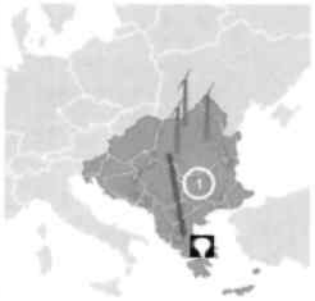
WHY CAO?

Trader has to win 3 auctions with

- 3 different Auction system
- 3 different Product
- 3 different Time Horizons

A successful transaction is only possible if the trader wins all 3 auctions.

CAO APPROACH

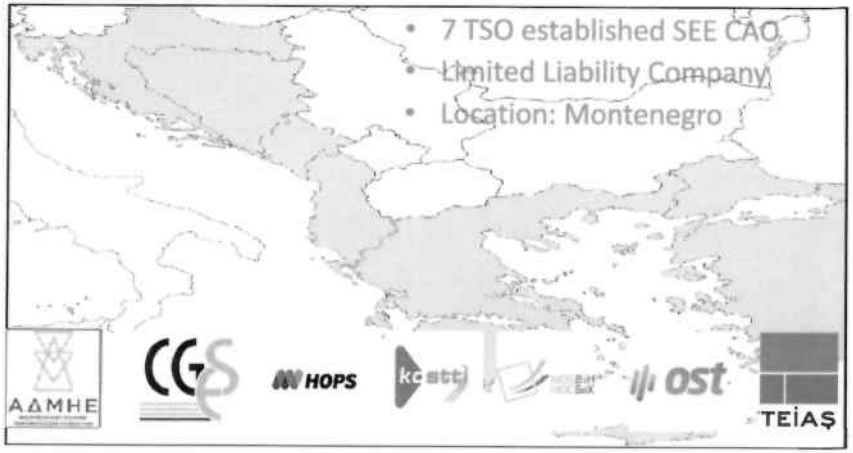


Only:

- 1 Auction System
- 1 Product
- 1 Time Horizon

Traders bid for a source sink combination and a loadflow calculation software analyzes the possible power flows in the grid

SEE CAO SHAREHOLDERS

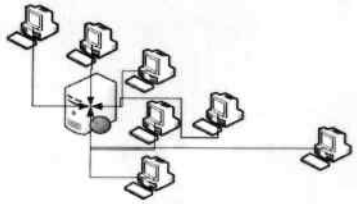


BENEFITS

- 1st successful regional project
- Trading in 7 countries
- One-stop shop
- Common rules & procedures
- Following of the EU legislative
  - in EU and non EU countries
- New products in SE energy market
- Provided transparency – connection with ENTSO-E Transparency Platform

TECHNICAL APPROACH

- 7 different systems → Single Auction Platform located in Podgorica
- http://www.seecao.com



- Web based application
- Synchronised auctions
- Single procedure, standard, rules, registration

TURKISH ELECTRICITY TRANSMISSION COMPANY

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BLACKOUT ON 31ST MARCH

TURKISH ELECTRICITY TRANSMISSION COMPANY

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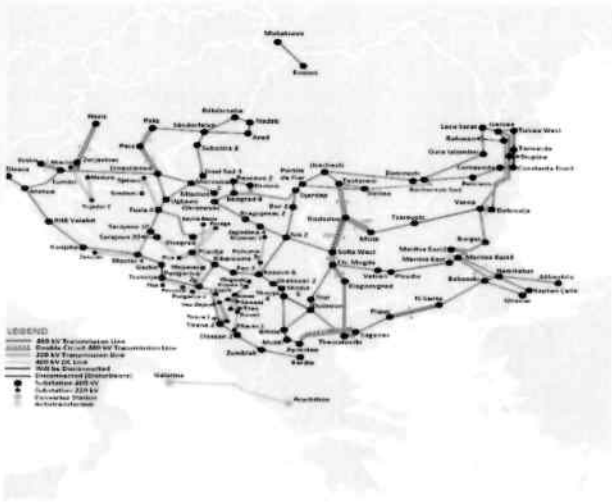
SYSTEM CONDITIONS BEFORE THE BLACKOUT



- Ordinary working day
- Medium load demand
- Main maintenance period for TR
- Spring water regime with full load operation of hydro power plants in Eastern Turkey
- Heavy loadlow for TR East->West transmission system corridor

TURKISH ELECTRICITY TRANSMISSION COMPANY

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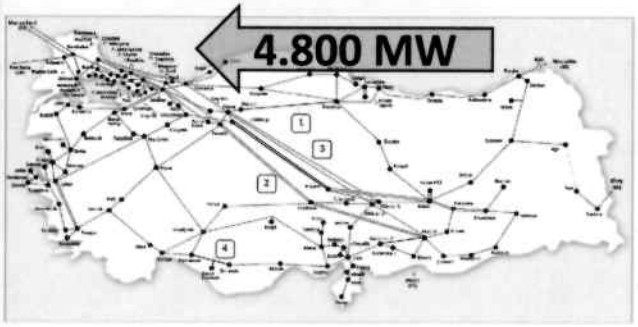
SYSTEM CONDITIONS BEFORE THE BLACKOUT



- Scheduled line outages due to maintenance and system expansion
  - (4 out of 11 in East-Wear Corridor)
- Series capacitors for long transmission lines out of service

- 32950 MW system load
- 500 MW import from CE
- 4800 MW east -> west power flow
- 21870 MW west load
- 11080 MW east load
  - 21% imbalance west
  - 42% imbalance east

TURKISH ELECTRICITY TRANSMISSION COMPANY

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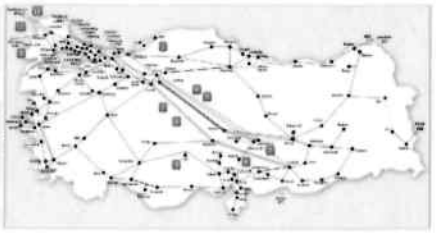
SEQUENCE OF EVENTS

#	Line/Event	Delta (sec)	Time (h:min:sec.fsec) in CET	Active Power (MW)	Reactive Power (MVAr)	Voltage (kV)	Current (A)	Comments
1	Kursunlu-Osmanca	0	09:36:09.418	1127	510	393	1816	Tripped
2	Ataturk-Yesilhisar/Kuzey (North)	1.568	09:36:10.984	900	531	333	1400	Both Ataturk-Goksun SHM section and Goksun SHM-Yesilhisar sections of the Ataturk-Yesilhisar (North) TL open.
3	Seydisehir-Adana	1.597	09:36:11.015	867	597	296	2163	Tripped
4	Sincan-Elbistan B	1.724	09:36:11.142	813	587	249	1992	Tripped
5	Sincan-Elbistan A	1.736	09:36:11.204	422	1054	303	2180	Tripped
6	Ataturk-Yesilhisar/Guney (South)	1.825	09:36:11.245	484	1154	355	3080	Both Ataturk-Goksun SHM section and Goksun SHM-Yesilhisar sections of the Ataturk-Yesilhisar (South) TL open.
7	Temelli-Yesilhisar (North)	1.835	09:36:11.252	348	1035	315	1950	Tripped
8	Temelli-Yesilhisar (South)	1.899	09:36:11.317	51	1391	346	2500	Tripped
9	Babaeski(TR)-Nea Santa (GR)	2.023	09:36:12.441	440	265	130	2333	Tripped
10	Hamitabat(TR)-Maritsa East 3 (2)	2.024	09:36:12.442	335	230	100	2828	Phase A opens at 9:36:12.287
11	Hamitabat(TR)-Maritsa East 3 (1)	2.110	09:36:12.528	631	300	155	2036	Tripped



- First line trip in Kursunlu-Osmanca
- Second and following lines trip due to low impedance or out of step
- In 3.1 seconds TR arrives in two islands
- In 10-12 seconds total system blackout

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ACTIVATED DEFENCE PLANS

- Interface Special Protection Scheme
- Underfrequency load shedding
  - Four steps
  - 49.0 Hz; 48.8 Hz; 48.6 Hz; 48.4 Hz
  - Current setting = 35.5% load at 48.4 Hz
- 52.3 Hz eastern island
- 48.2 Hz western island
- Power plant disconnections due to high frequency deviations

Region	West Island		East Island	TOTAL
	SPS	UFLS		
Thrace	252 MW	1641 MW		1893 MW
Northwest Anatolia	125 MW	1018 MW		1143 MW
West Anatolia		1059 MW		1059 MW
Southwest Mediterranean		516 MW		516 MW
Middle Anatolia		583 MW	204 MW	787 MW
Northeast Anatolia			242.2 MW	242.2 MW
East Anatolia			0	0
Southeast Anatolia			683 MW	683 MW
Southeast Mediterranean			1148.1 MW	1148.1 MW
TOTAL	377 MW	4817 MW	2277.3 MW	7471.3 MW

Frequency Range	Minimum duration
51,5 Hz ≤f≤ 52,5 Hz	10 minutes
50,5 Hz ≤f< 51,5 Hz	1 hour
49 Hz ≤f< 50,5 Hz	Permanent
48,5 Hz ≤f< 49 Hz	1 hour
48 Hz ≤f< 48,5 Hz	20 minutes
47,5 Hz ≤f< 48 Hz	10 minutes

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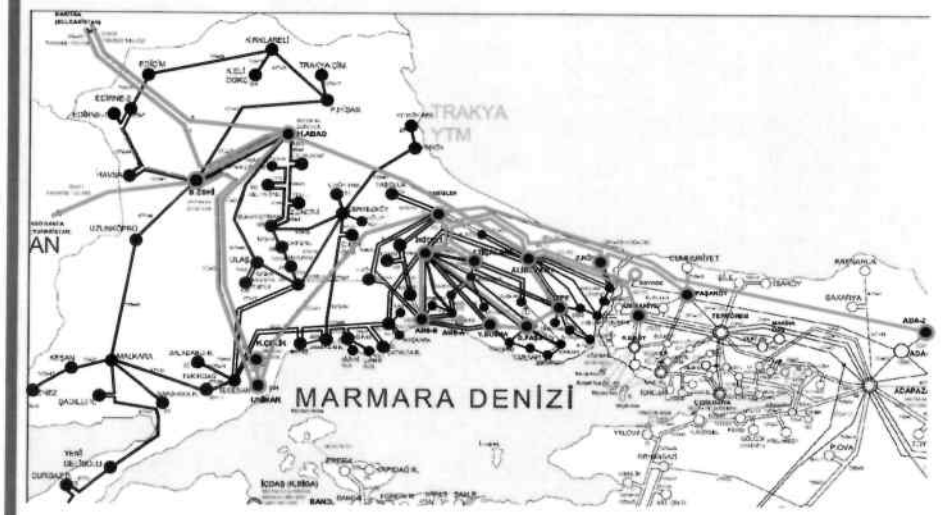
RESTORATION

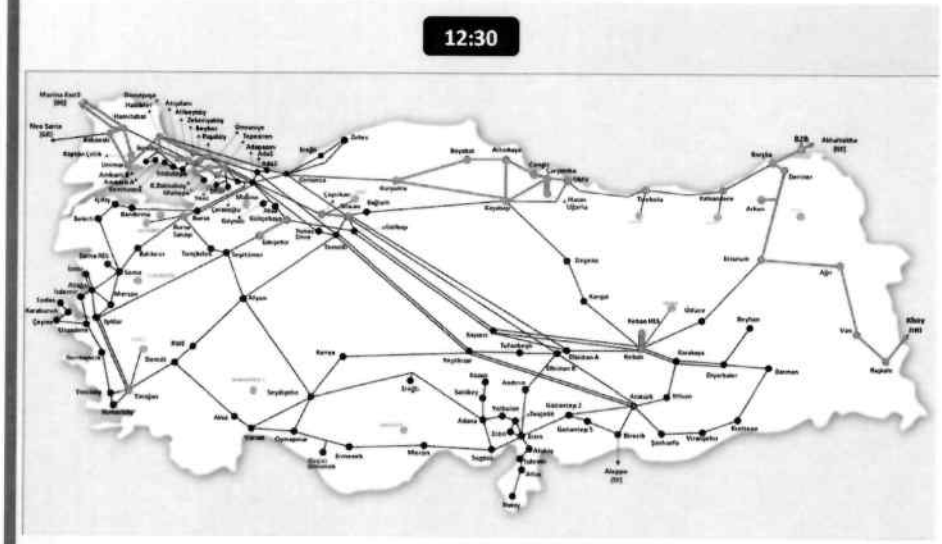
- Top-down (CE) and bottom-up (9 regional centers) procedures in parallel
- Start with TR-BG connection after 18 minutes
- After 1 ½ hours 50% of Trace region was energised
- East-West synchronisation at 16:12 (after 6.5 hours) – 80% of load restored
- Mobile communication was not affected
- Airline traffic was not affected

Time (CET)	Percentage of system load restored
09:36	Blackout
12:00	20%
14:30	50%
16:12	80%
18:30	95%

RESTORATION PHASE



RESTORATION PHASE



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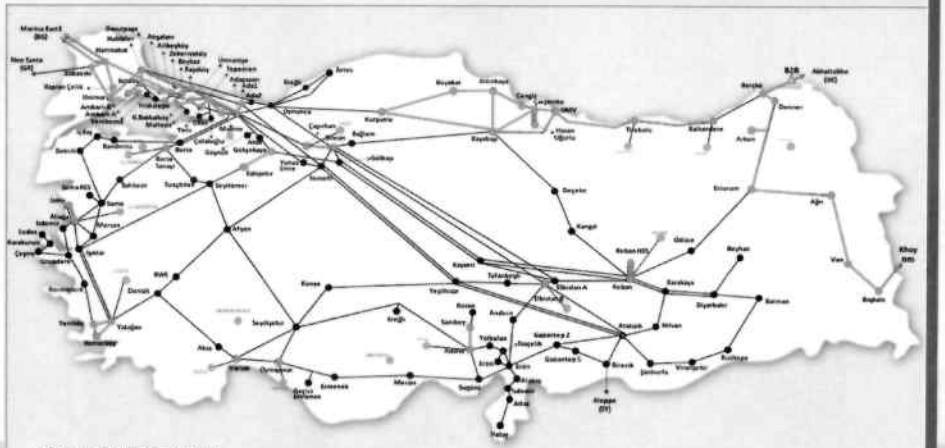
RESTORATION PHASE

13:00(EET) %20 Completed

13:30



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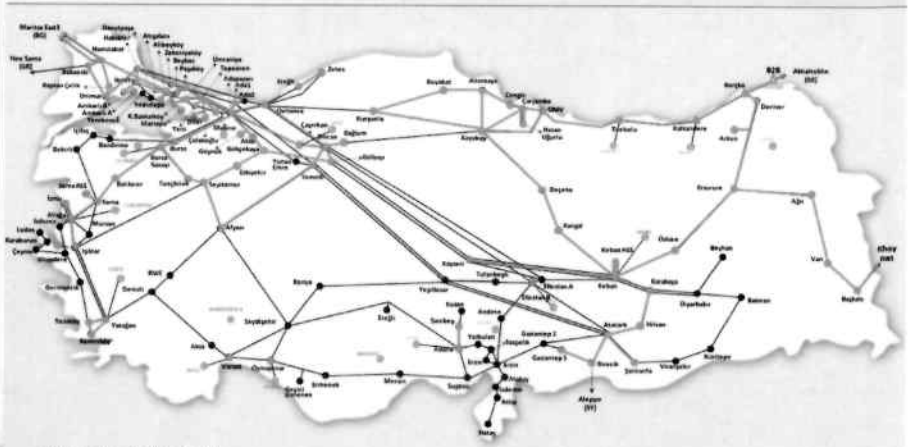
RESTORATION PHASE

15:30(EET) %50 Completed

15:30



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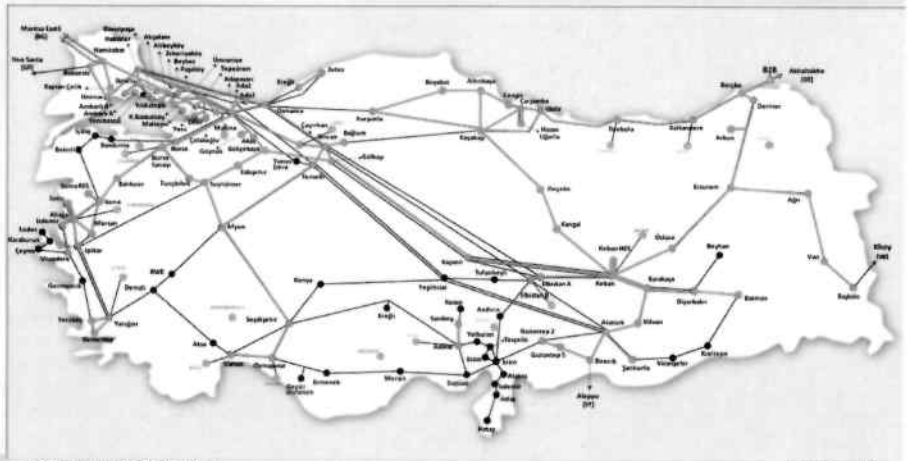
RESTORATION PHASE

17:12(EET) %80 Completed

49.90 Hz | 17:00 | 49.65 Hz



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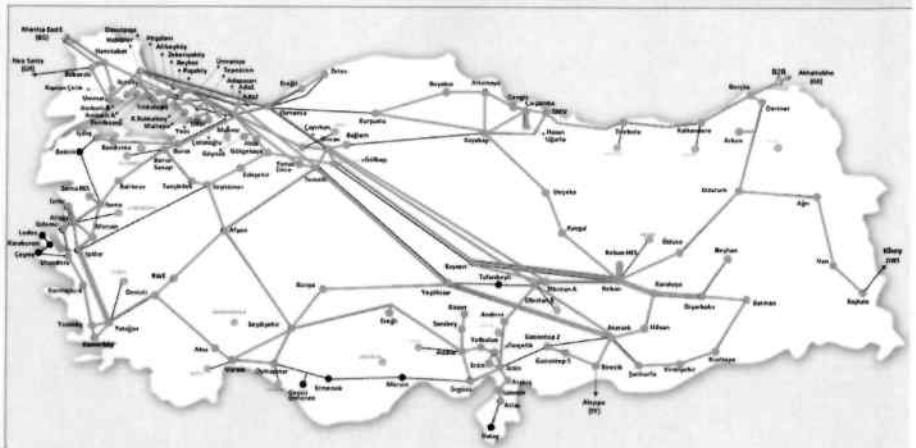
RESTORATION PHASE

19:30(EET) %95 Completed

50.02 Hz | 19:30 | 50.02 Hz



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MAIN CAUSES

- Uncoordinated transmission line outages
- Disconnection of series capacitors
- Incomplete SCADA system functionality
- System operation close to operational margins
- Non-conform power plant protection settings
- Insufficient underfrequency load shedding

REPORT

TEİAŞ entsoe

Report on Blackout in Turkey on 31st March 2015

– Final Version 1.0 –

Project Group Turkey

21 September 2015

- Available in ENTSO-E and TEIAS web sites

Report Authors:

- TEIAS experts
- PG Turkey members
- SPD experts

Source of Data & Information:

- TEIAS maps, operational database
- WAM measurements
- TSO & PP SCADA recordings
- TSO timely high resolution recordings

Thank you for your attention!

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