Karnataka's Energy Mix: Computational Model for Energy Planning

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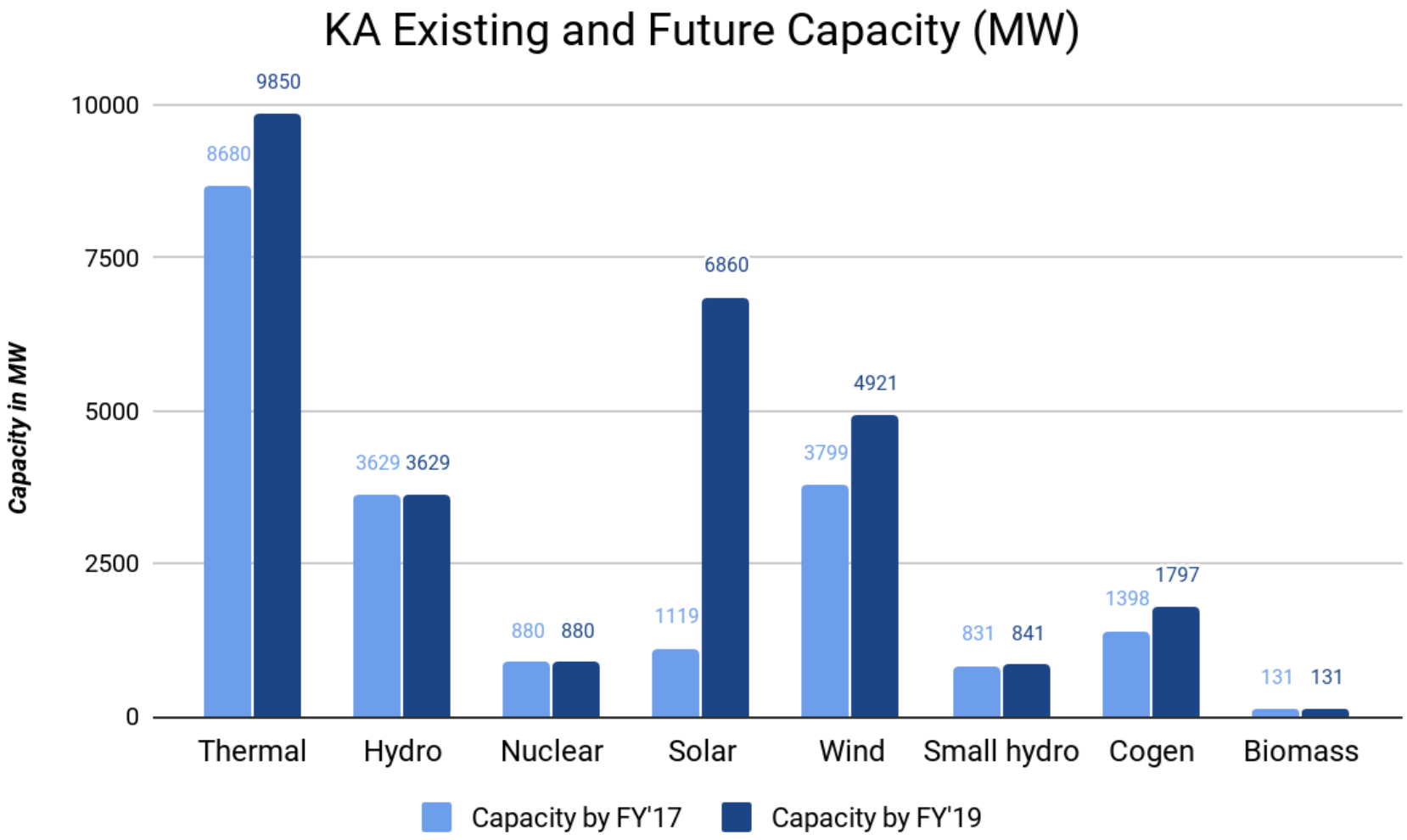
9th Jan, 2019

Outline

- Background & Rationale
- Objectives
- Methodology
- Results

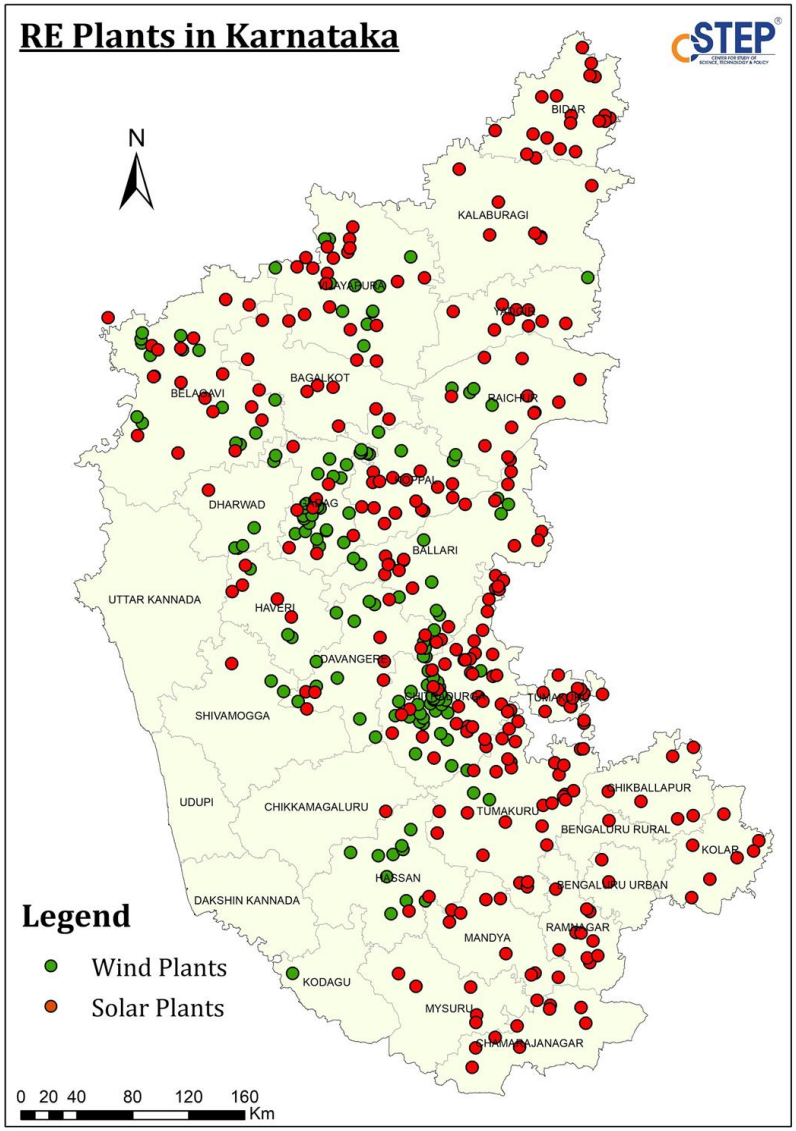
Background & Rationale

Large RE Capacity Addition Plans



Source: KPTCL, KREDL and CEA

RE Geographically Dispersed & Intermittent



Solar plants are predominantly concentrated in:

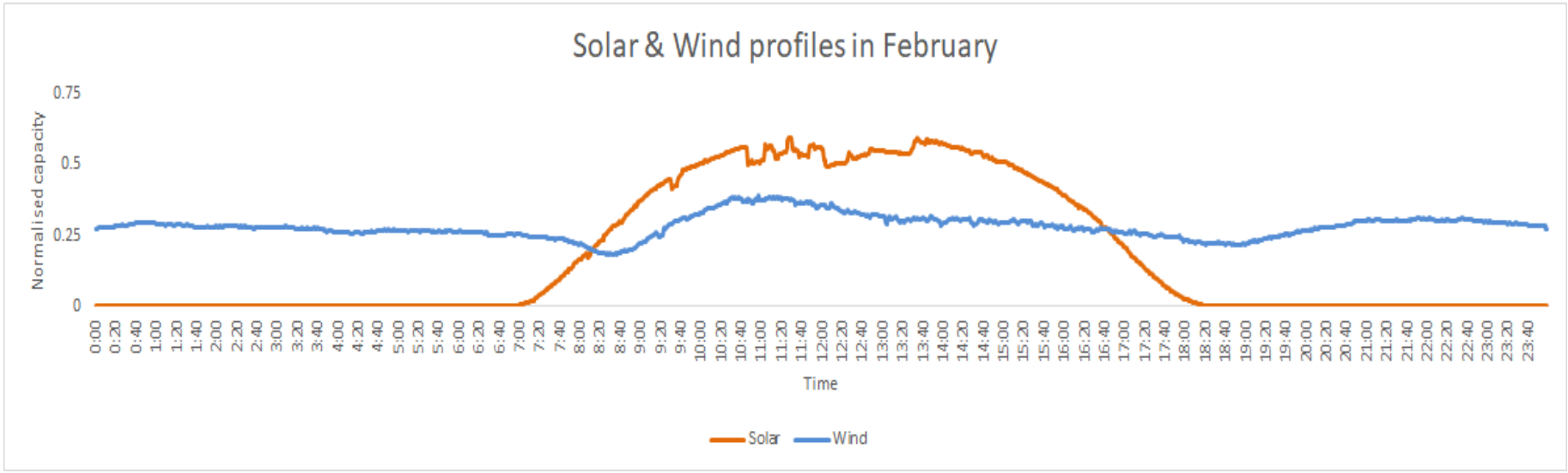
- Tumakuru
- Chitradurga
- Bidar
- Ballari
- Raichur districts

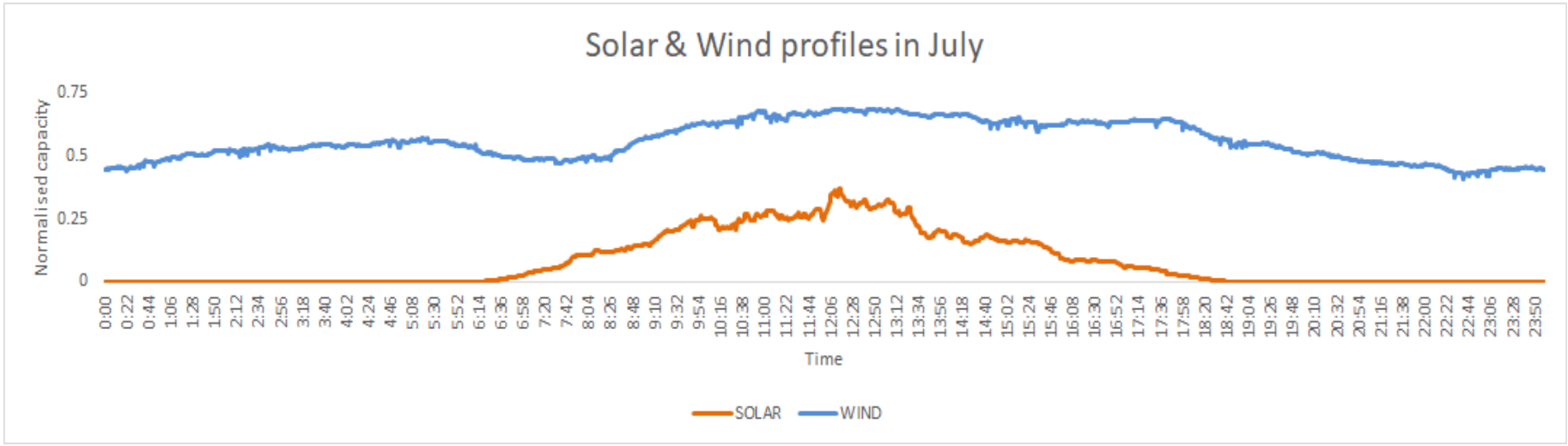
Wind plants are predominantly concentrated in:

- Gadag
- Chitradurga
- Davanagere
- Belagavi
- Vijayapura districts

Source : Data obtained from KREDL as on March 31, 2018, CSTEP analysis

Intermittency of Solar & Wind generation





Objectives

- How does the state plan for large scale integration of Renewable Energy (RE) sources?
  - Identify network constraints
  - Assess strengthening requirements
  - Estimate associated investments
- Develop Power Systems Model for Transmission planning

Methodology

Methodology

Network modeling & validation

- Load flow model using ETAP software
- 540 Sub Stations – 765, 400, 220, 110 kV
- Validation of base case with SCADA

Addition of Future RE Generators

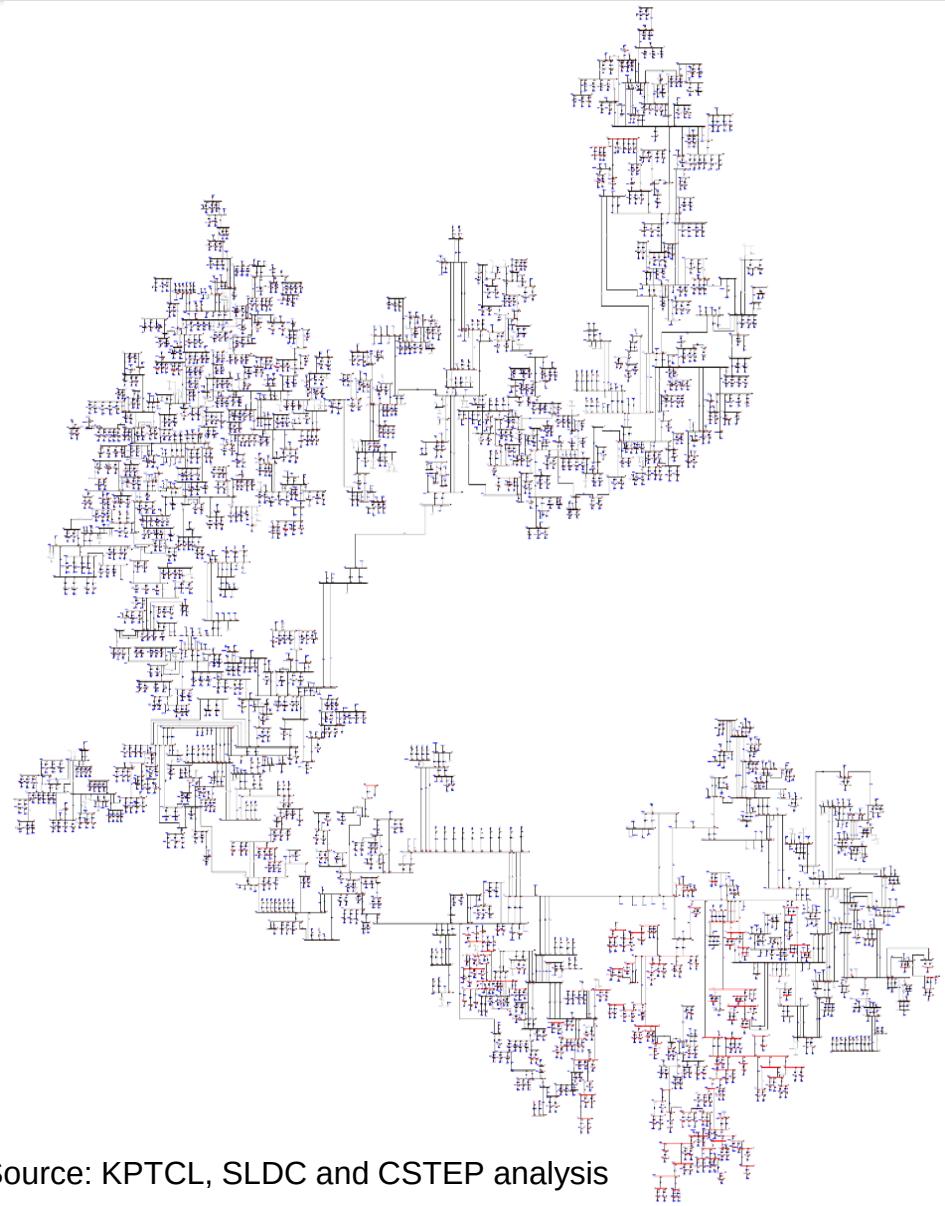
Scenario Analysis – Stress Test

- State peak and off peak loads
- Peak and off peak solar
- Peak and off peak wind

Analysis & Recommendations

- Transmission strengthening needs
- Investments required

Transmission Network in ETAP



Substation details for FY 2018-19	
Substation Voltage (kV)	**Number of substations**
765/400	2
400/220	22
220/110/66	108
110/33/11	408
Total	**540**

Source: KPTCL, SLDC and CSTEP analysis

Scenarios Selected

#	Scenario*	Day	Time
1	State peak load	March 30	10 AM
1(a)	State off peak load	October 15	3 AM
2	Peak solar generation	February 16	1 PM
2(a)	Off peak solar generation	February 16	7 PM
3	Peak wind generation	July 15	3 PM
3(a)	Off peak wind generation	May 5	12 PM

* In consultation with KPTCL & SLDC officials

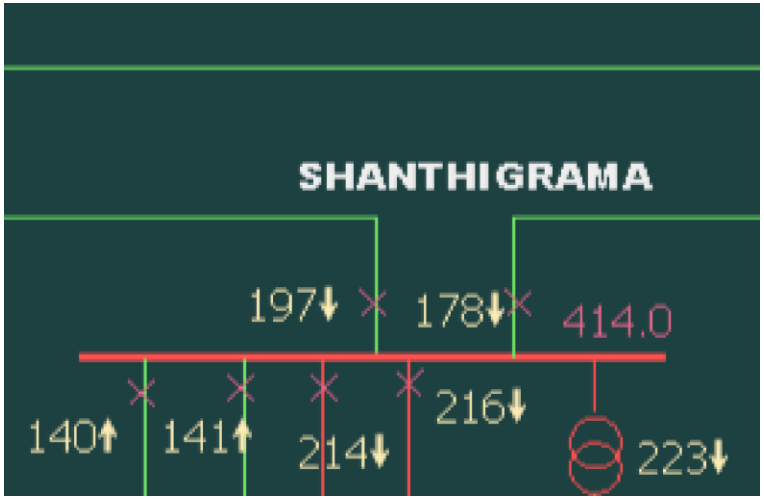
Data Sources

Category	Data Type	Source	Dataset
RE data	Primary data	KREDL	Existing solar plants (Capacity & Location) Existing wind plants (Capacity & Location) Proposed/Planned wind plants for 2017-18 & 2018-19 in Karnataka Proposed/Planned solar plants for 2017-18 & 2018-19 Existing & Proposed co-generation plants Existing & Proposed biomass plants Existing & Proposed small hydro plants
		KPTCL	Substation connectivity for existing solar plants (partial) Substation connectivity for existing wind plants (partial)
Network data	Primary Data	KPTCL	Existing transmission line data – 110 kV and above voltage level Substation data – 110 kV and above voltage level buses Transmission network geographical map GIS locations for substations (Latitude and Longitude along with pin code) Proposed transmission network up to 2018-19 Conventional generators – (thermal, hydro, nuclear) Reactor details (partial)
		SLDC	SCADA snapshots of transmission network for validation Transmission line parameters along with line lengths Inter-state transmission lines Scenario dates Grid reactors
		PCKL	Existing & proposed central generating stations
	Secondary data	CEA reports	Status of transmission lines under construction details in Karnataka along with proposed lines Details of status of substation under construction in Karnataka along with proposed substation Commissioning status of thermal plants Central Generating Station details Transmission line parameters and rating for different types of conductors Permissible maximum and minimum voltage limits for planning studies Power factor to be considered for grid connected RE (solar & wind) plants Transmission network connectivity data for proposed solar park at Pavagada

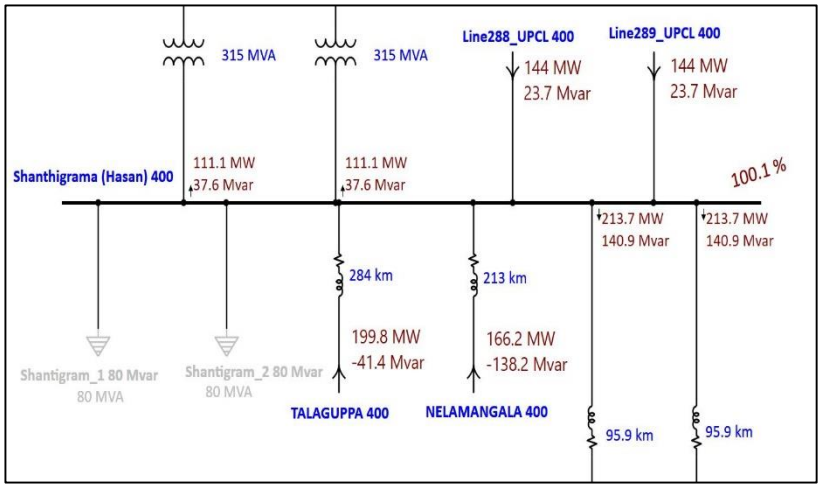
Results

Base Case Validation

SCADA Flows



ETAP Flows



- Line flows match SCADA values for 82% of 400 kV lines: < 10% difference
- Line flows match SCADA values for 91% of 220 kV lines: < 10% difference
- 400 kV bus voltages match SCADA values: < 4% difference

Analysis: Network Overloading(1/2)

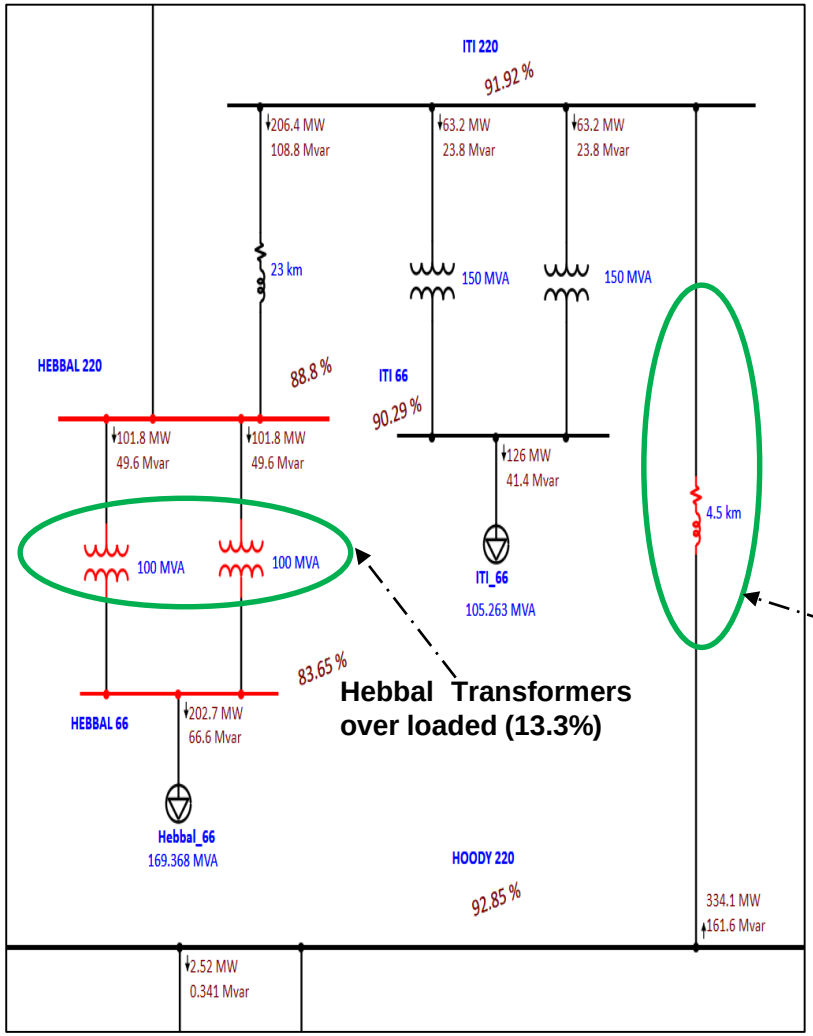
Scenario #	Condition	Instant	Findings
Scenario 1	State peak load	March 30th , 10 AM	· Three 220 kV lines and Six 110 kV lines overloaded · Two 220/66 kV substations overloaded
Scenario 1(a)	State off peak load	October 15th, 03 AM	· No overloading
Scenario 2	State peak solar	Feb 16th, 1 PM	· Two 220 kV line and Three 110 kV lines overloaded

Analysis: Network Overloading(2/2)

Scenario #	Condition	Instant	Findings
Scenario 2(a)	State off peak solar	Feb 16th, 7 PM	· Two 220 kV line overloaded
Scenario 3	State peak wind	July 15th, 3 PM	· Six 110 kV lines overloaded · One 220/110 kV substation overloaded
Scenario 3(a)	State off peak wind	May 5th, 12 PM	· Two 220 kV line overloaded

Scenario 1– State Peak Load (30 Mar 10 AM)

ITI to Hoody line over loaded (48%)



Hebbal Transformers over loaded (13.3%)

ITI to Hoody line over loaded (48%)

Transmission line overloadings:

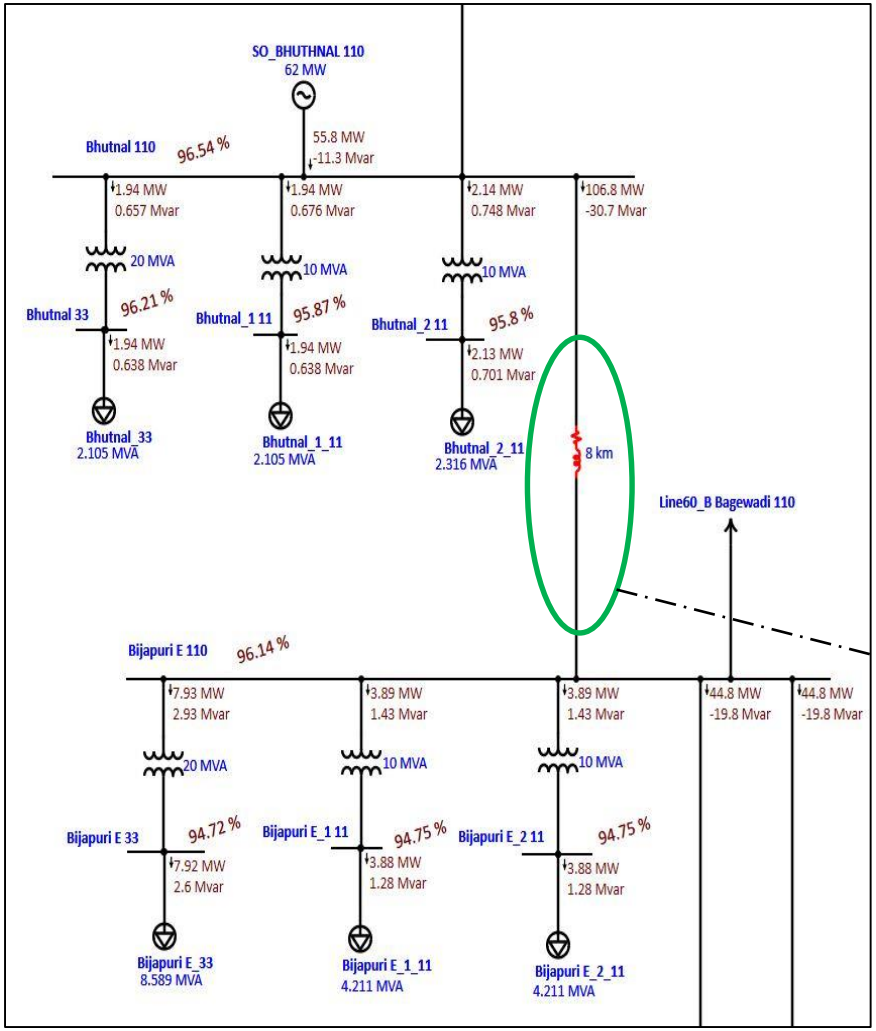
- 3 lines overloaded more than 30%
- 3 lines overloaded more than 5%
- 3 lines overloaded more than 2%

Substation overloadings:

- Hebbal 220/66 kV
- Naganathapura 220/66 kV

Scenario 2 - Peak Solar (16 Feb, 1 PM)

Bhutnal to Bijapur line over loaded (57%)



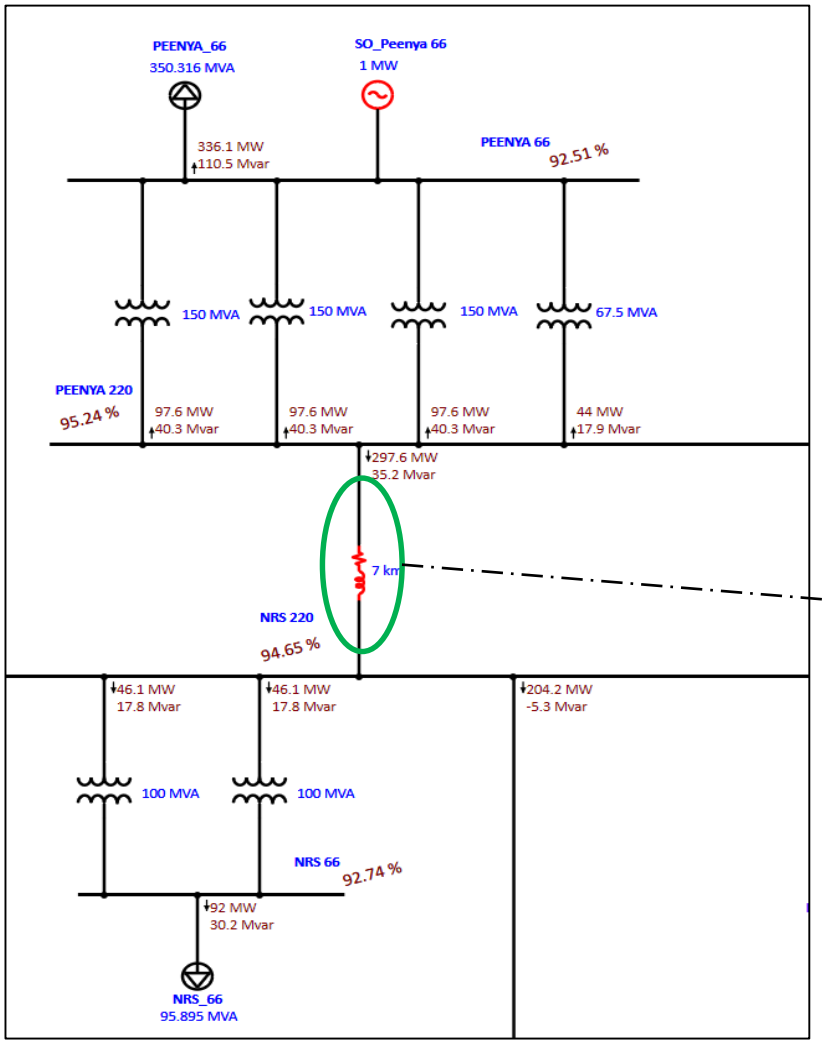
Transmission line overloadings:

- 2 lines overloaded more than 30%
- 3 lines overloaded more than 5%

Bhutnal to Bijapur line over loaded (57%)

Scenario 2(a) - Off Peak Solar (16 Feb, 7 PM)

Peenya to NRS line over loaded (16.3%)



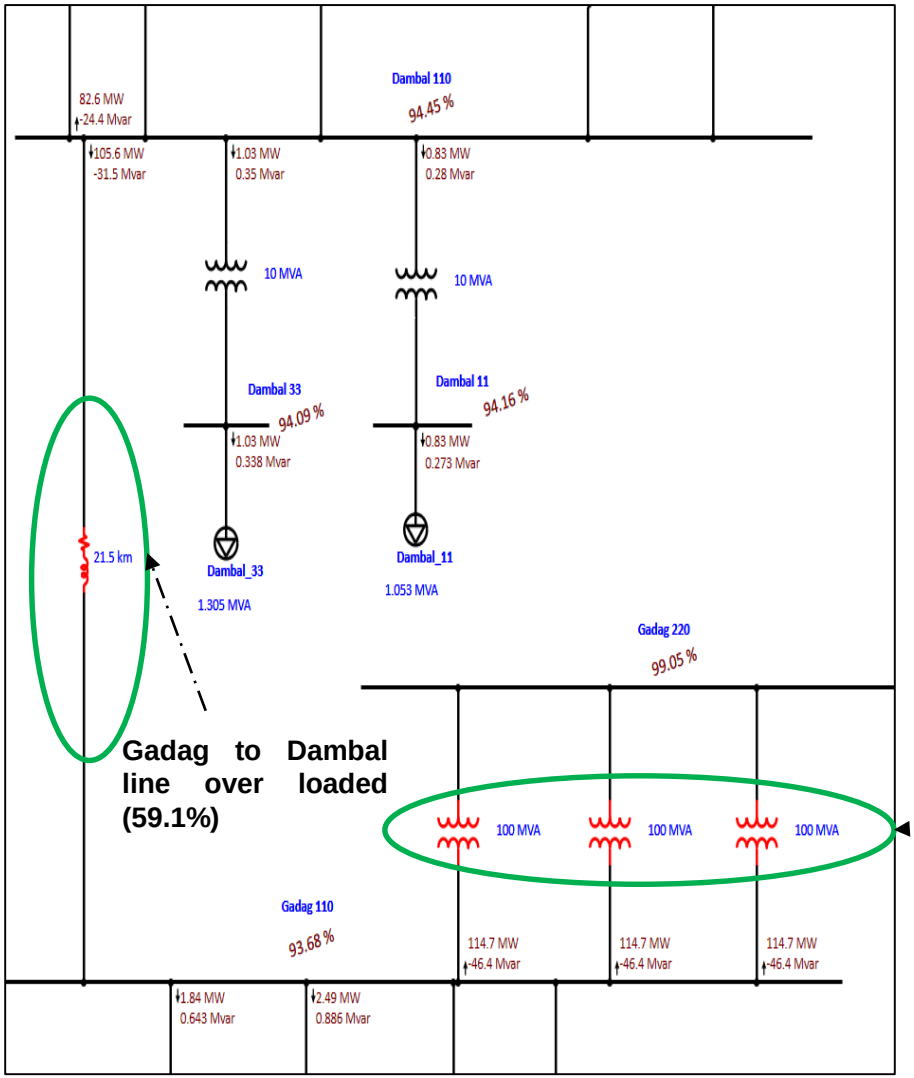
Transmission line overloadings:

- 2 lines overloaded more than 10%

Peenya to NRS line over loaded (16.3%)

Scenario 3 –Peak Wind (15 July 3 PM)

Gadag Transformers over loaded (30.8%)



Transmission line overloadings:

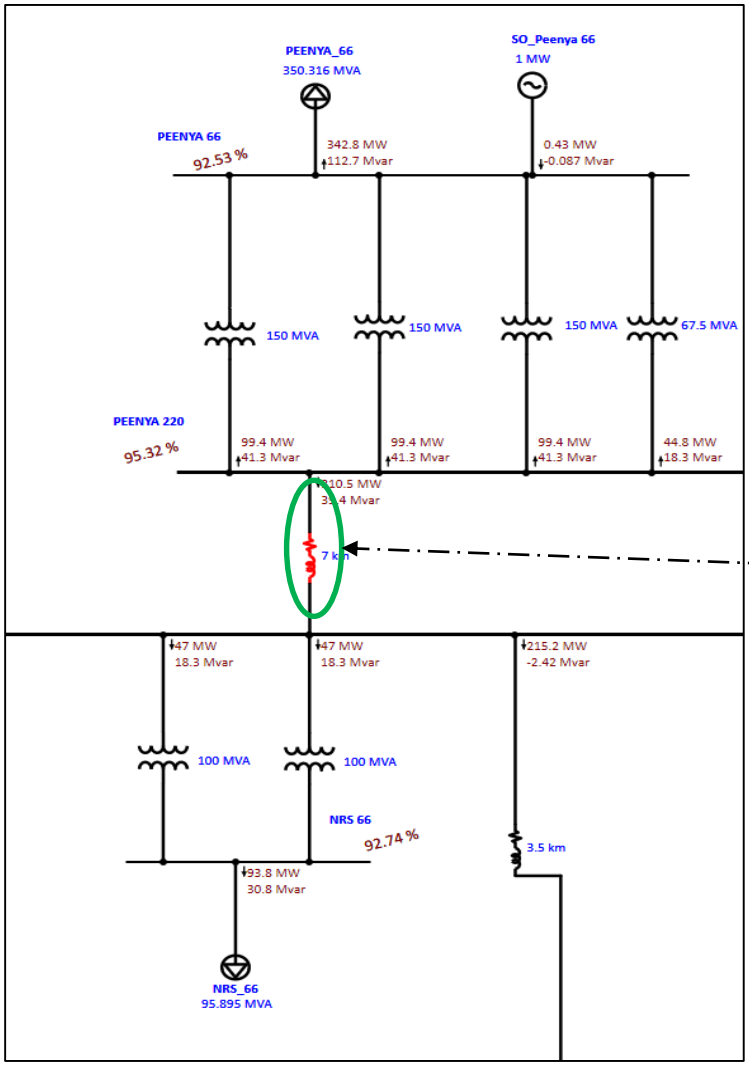
- 4 lines overloaded more than 30%
- 2 lines overloaded more than 20%

Substation overloadings:

- Gadag 220/66 kV

Scenario 3(a) –Off Peak Wind (5 May 12 PM)

Peenya to NRS line over loaded (21.4 %)



Peenya to NRS line over loaded (21.4 %)

Transmission line overloadings:

- 2 lines overloaded more than 10%

Investments for Strengthening

#	Proposed transmission line upgrade	Line length (km)	Line cost (in INR crore)	Total cost (in INR crore)
1	New 220 kV D/C 1000 sq.mm XLPE cable from Bidadi 400/220 kV SS to Vrishabhavathi 220/66 kV SS	22	506.0	**512.0**
2	New 220 kV S/C line from Peenya 220/66 kV SS to NRS 220/66 kV SS	7	5.0	8.0
3	LILO of 110 kV S/C line from Gurupura 110 kV SS to Kavoor 220 kV SS at Baikampady 110 kV SS	6.6	3.0	3.8
4	New 110 kV S/C line from Tikota 110 kV SS to Bijapur E 110 kV SS via Tekkalakki, Torvi and Bhutnal 110 kV SS	40	12.4	15.6
5	New 110 kV S/C line from Yelburga 110 kV SS to Kustagi 110 kV SS	28	8.7	9.5
6	New 110 kV S/C line from Dongargaon 110 kV SS to Halabarga 110 kV SS via Santpur 110 kV SS	70	21.7	23.3
7	New 220 kV D/C line from Dambal 220/110 kV SS to Dhoni 400/220 kV SS	5.5	3.6	9.6
8	New 110 kV S/C line from Dambal 220/110 kV SS to Mundargi 110 kV SS	19	5.9	6.7
9	New 110 kV S/C line from Mundargi 110 kV SS to VSPL (wind generation pooling point)	18	5.6	6.4
Total investment required for transmission lines (A)				**595**

#	Proposed substation upgrade	Transformer addition (MVA)	Total cost (in INR crore)
1	Addition of 3rd 100 MVA transformer at Naganathpura 220/66 kV SS	100	9
2	Upgradation of existing Dambal 110/11kV SS to 220/110/11 kV SS with addition of 2×100 MVA, 220/110 kV transformers.	200	41
Total investment required for substations (B)			**50**

Total investment required: 645 crores

Impact of Taluk-wise Limits

Examined the feasibility of 200 MW Solar and 100 MW Wind per taluk

Solar: Koppal, Sindhanur, Lingasagur - Feasible;

Sedam & Jewargi - *Strengthening required*

Wind: Belgaum, Yelburga, Bailahongal, Ranibennur & Basavana Bagewadi - Feasible

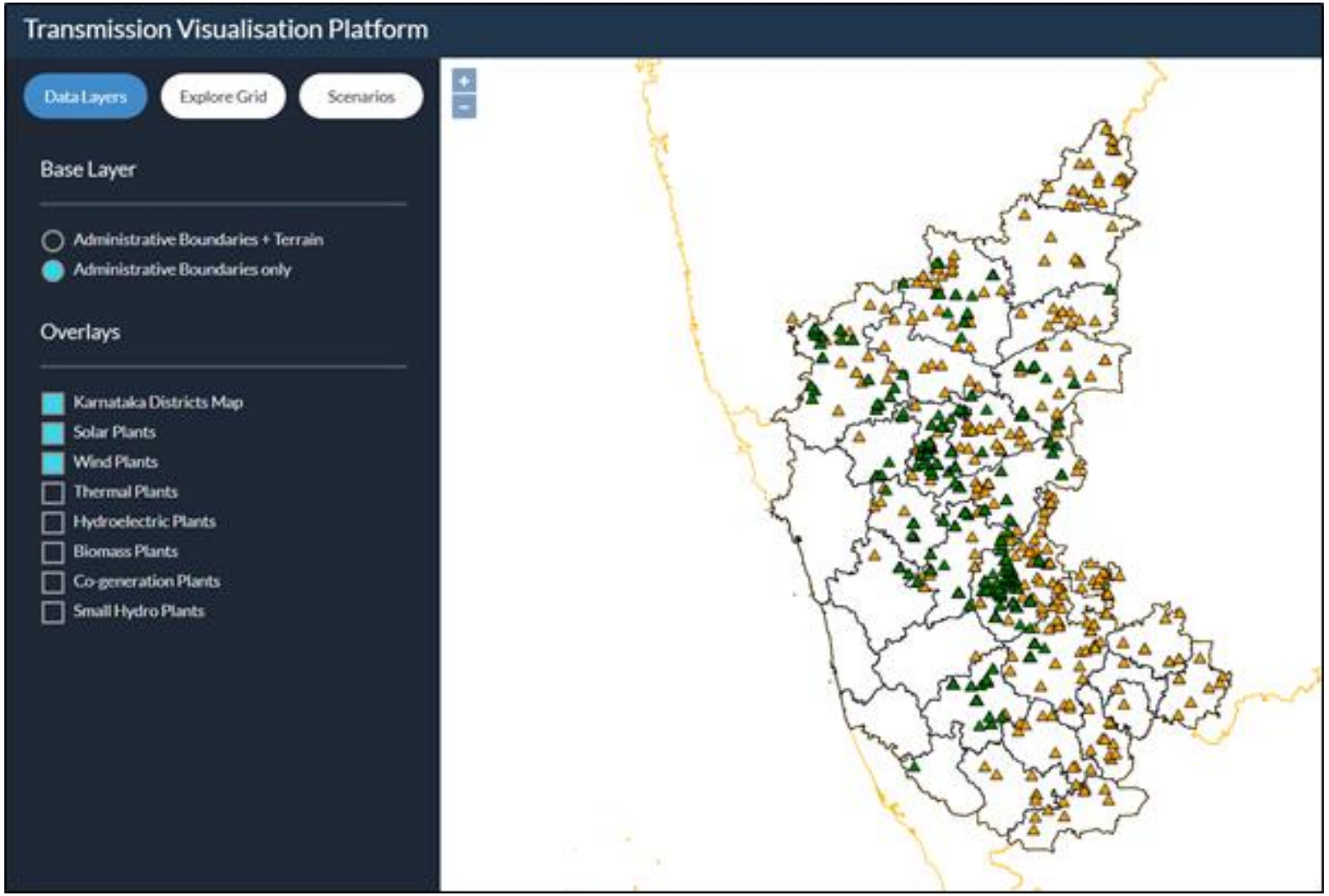
Hybrid: Bellary, Bidar, Indi, Chikkodi & Raibaga - Feasible

Key Findings

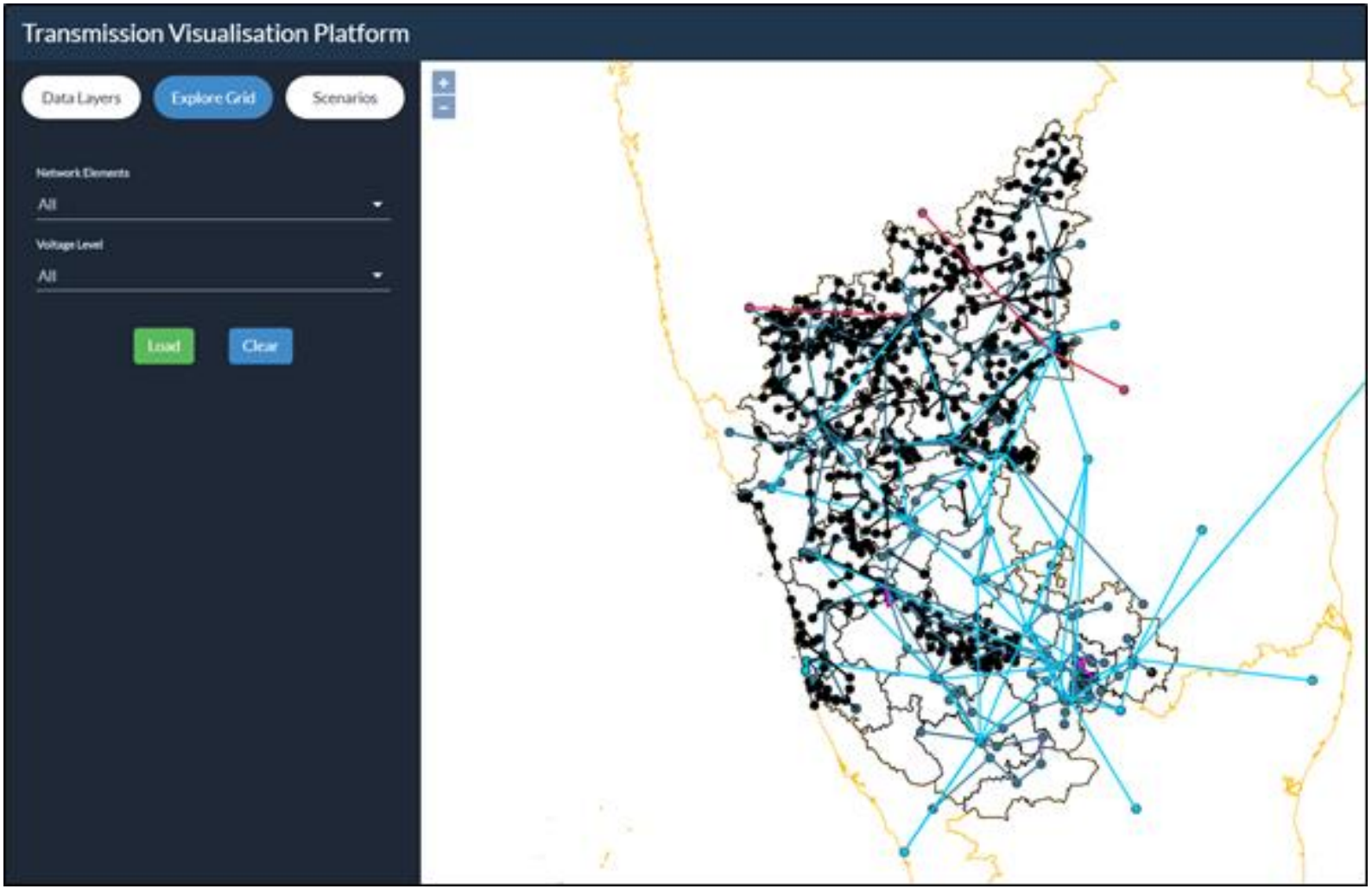
- 18 transmission lines and 3 substations (220 kV) overloaded - more than 100%
- RE power sufficient to meet projected state demand under peak solar and peak wind instants
- BMAN projected to experience load of around 3883 MW
  - 3 lines (220 kV) overloaded - more than 100%
  - 12 lines (220 kV) loaded - more than 80%
- Cumulative Investments INR 645 Crores
- Power Sector Visualisation platform developed for Transmission planning

  http://darpan.cstep.in/energy_pp/

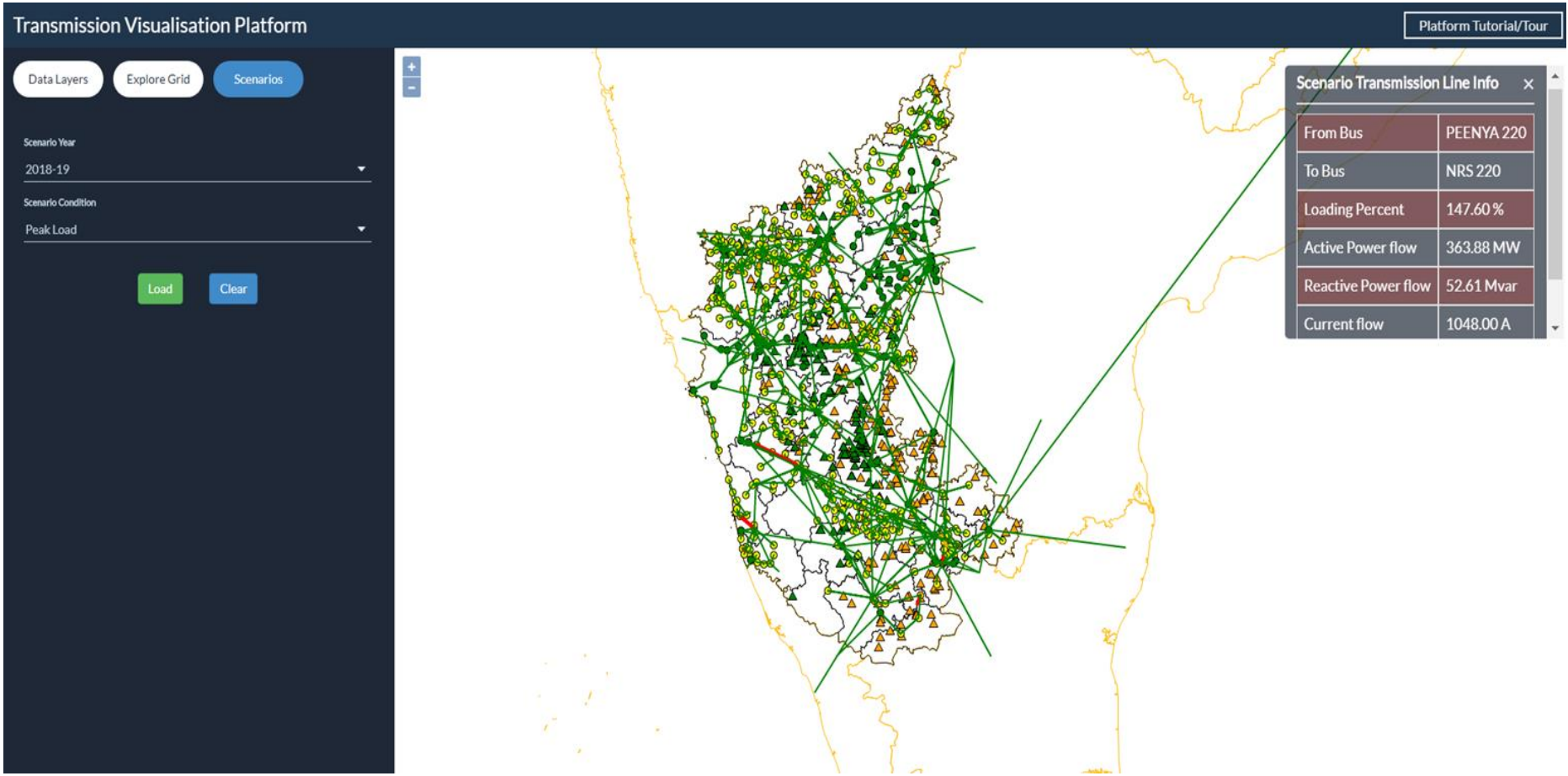
Visualisation Platform - RE plants



Visualisation Platform - Network



Visualisation Platform - Scenario



THANK YOU

Study Assumptions

- Talcher - Kolar HVDC link: Slack bus
- CGS generators: Scheduled to their rated capacity negating auxiliary consumption
- Auxiliary consumption:
  - Thermal and nuclear: 8.5%
  - Hydro: 1%
- Power factor for RE plants: 0.98 (absorbing)
- Inter-Connecting Transformer (ICT) impedance: 12.5 % on its own base MVA
- Interstate import/export lines: Modelled as lumped generators/loads
- Loads: Modelled at 66/33/11 kV buses of 220 kV and 110 kV substations with 0.95 PF lag
- Network validation instant: 5th May, 2017 @10.09 AM (using SLDC SCADA snapshot)
- RE plants connectivity: Nearby 110 kV or 220 kV substations based on their geographical location
- RE plants must run status and CGS plants prioritised for scheduling over state conventional generators

Load Generation Balance for FY 2018-19

#	Particulars (Total installed capacity in MW)	Scenario 1	Scenario 1(a)	Scenario 2	Scenario 2(a)	Scenario 3	Scenario 3(a)
		State peak load	State off peak load	Peak solar	Off peak solar	Peak wind	Off peak wind
1	State hydro (3,629)	1,586	488	0	1,528	286	1,183
2	State thermal – coal (7,450)	2,602	0	0	2,199	0	732
3	CGS - Nuclear + Thermal (3,280)	3,001	3,001	0	3,001	805	3,001
4	Solar (6,860)	2,470	0	6,174	0	1,029	2,950
5	Wind (4,921)	246	443	1,526	1,083	3,937	14
6	Co-generation (1,757)	53	88	53	53	53	70
7	Biomass (131)	3	3	12	12	4	4
8	Small Hydro (841)	34	244	17	17	135	42
9	RE total (4+5+6+7+8)	2,806	778	7,782	1,165	5,158	3,080
10	State thermal – gas (370)	100	100	0	100	56	100
11	Import	4,397	4,109	4,127	4,296	4,211	4,201
Total power available (1+2+3+9+10+11)		**14,492**	**8,476**	**11,909**	**12,289**	**10,516**	**12,297**
12	Load	11,325	5,596	8,911	9,223	7,535	9,327
13	Export	2,724	2,724	2,724	2,724	2,724	2,724
14	Losses	443	156	274	342	257	246
Total power consumed		**14,492**	**8,476**	**11,909**	**12,289**	**10,516**	**12,297**

Findings: Taluk-wise Solar Feasibility

#	Taluk	Substation	RE capacity connected (MW)	Feasibility for RE evacuation	Reason if not feasible	Suggestion
1	Koppal	Betagera 110 kV	27	Feasible	-	-
		Ginigere 110 kV	40			
		Koppal 110 kV	63			
		Kerehalli 110 kV	70			
2	Sindhanur	Dadesugur 110 kV	40	Feasible	-	-
		Sindhanur 220 kV	40			
		Sindhanur 110 kV	70			
		Turvihal 110 kV	40			
		Walkamdinni 110 kV	10			
3	Sedam	Kurkunta 110 kV	53	Not feasible	Sedam 2×100 MVA, 220/110 kV substation will be overloaded	Addition of 3rd 100 MVA transformer at Sedam 220/110 kV substation
		Sedam 220 kV	147			
4	Jewargi	Jewargi 110 kV	90	Not feasible	110 kV S/C line from Shahabad to Jewargi will be overloaded	New 110 kV S/C line is required from Shahabad to Jewargi
		Mandewal 110 kV	110			
5	Lingasugur	Gurugunta 110 kV	20	Feasible	-	-
		Hutti 110 kV	16			
		Lingasugur 220 kV	114			
		Mudgal 110 kV	50			

Findings: Taluk-wise Wind Feasibility

#	Taluk	Substation	RE capacity connected (MW)	Feasibility for RE evacuation
1	Belgaum	Belgaum 220 kV	60.4	Feasible
		Udaymbag 110 kV	9.6	
		Kanabaragi Layout 110 kV	10	
		Mache 110 kV	0	
		Vadagaon 110 kV	10	
		Suvarna Soudha 110 kV	0	
		Uchagaon 110 kV	10	
		Hirebagewadi 110 kV	0	
2	Yelburga	Bevoor 110 kV	50	Feasible
		Ganadal 110 kV	50	
		Yelburga 110 kV	0	
3	Basavana Bagewadi	Basavana Bagewadi 220 kV	261.2	Feasible. Already 335.2 MW of wind power plants are planned in this taluk by end of FY 2018-19 and it can be evacuated without any network constraints.
		Mukarthihal 110 kV	74	
		Mattihal 110 kV	0	
		Nidagundi 110 kV	0	
		Malghan 110 kV	0	
4	Bailahongal	Bailahongal 110 kV	30	Feasible
		MK Hubli 220 kV	30	
		MK Hubli 110 kV	20	
		Kittur 110 kV	10	
		Udakeri 110 kV	10	
5	Ranebennur	Aremallapur 110 kV	30	Feasible
		Ranebennur 220 kV	40	
		Tumminakatte 110 kV	30	

Findings: Taluk-wise Hybrid Feasibility

#	Taluk	Substation	RE capacity connected (MW)	Feasibility for RE evacuation
1	Bellary	Alipura R/S 220 kV	0	Feasible. Around 123.1 MW of RE plants (Solar + Wind) are planned in Bellary taluk by FY 2018-19 and the power can be evacuated with existing network infrastructure without having any network constraints
		Bellary (N) 110 kV	0	
		Bellary (S) 110 kV	0	
		Kurugod 110 kV	56.1	
		Moka 110 kV	0	
		PD Halli 110 kV	43	
		Somasamudra 110 kV	0	
		Torangal 110 kV	0	
		Kudithini 110 kV	0	
		Halakundi 110 kV	24	
2	Bidar	Chidri 110 kV	10	Feasible
		Habsikote 110 kV	18	
		Janawada 110 kV	20	
		Kamthana 110 kV	19	
		Halbarga 220 kV	18	
		Kolhar 110 kV	15	
3	Indi	Atharga 110 kV	54	Feasible. Already 180.2 MW of wind power plants are planned in this taluk by end of FY 2018-19 and it can be evacuated without any constraint in the grid
		Indi 220 kV	126.2	
		Indi 110 kV	0	
		Hirebevanur 110 kV	0	
		Lachyan 110 kV	0	
		Zalaki 110 kV	0	
4	Chikkodi	Ankali 110 kV	0	Feasible. Already 106.45 MW of wind power plants are planned in this taluk by end of FY 2018-19 and it can be evacuated without any constraint in the grid
		Bhoj (Galatga) 110 kV	35.85	
		Boregaon 110 kV	0	
		Chikkodi 220 kV	0	
		Chikkodi 110 kV	50	
		Kabbur (Nagar munnolli) 110 kV	20.6	
		Nippani 110 kV	0	
		Sadalaga 110 kV	0	
		Nanadi 110 kV	0	
5	Raibaga	Hidakal 110 kV	0	Feasible
		Kudachi 220 kV	10	
		Kudachi 110 kV	10	
		Raibag 110 kV	4	
		Itnal 110 kV	66.6	
		Kagwad 110 kV	0	
		Sultanpur 110 kV	9.4	
		Mantur 110 kV	0	

Findings: Strengthening Requirement(1/2)

#	Overloaded element	Occurrence	Reason(s)	Recommendation(s)
1	220 kV S/C line from Somanahally to Tataguni	Scenario 1	Increase in load at Tataguni and Vrushabavathi substations	Setting up a new 220 kV D/C 1000 sqmm XLPE cable from PGCIL Bidadi 400/220 kV substation to Vrushabavathi 220/66kV substation
2	220 kV S/C line from Peenya to NRS	Scenario 2, Scenario 2(a), Scenario 3(a)	Increase in load at NRS, A station and EDC substation	Setting up an additional 220 kV S/C line from Peenya substation to NRS
3	220 kV S/C line from ITI to Hoody	Scenario 1, Scenario 2, Scenario 2(a), Scenario 3(a)	Increase in load at ITI and Hebbal 220 kV substations, radially fed from Hoody 220 kV substation	ITI 220 kV substation should be radially fed from Hoody 220 kV substation by keeping ITI to Hebbal 220 kV S/C line out of service Hebbal substation should be fed from Yelahanka and Nelamangala substations by keeping Hebbal-tap to Peenya 220 kV S/C line open
4	110 kV S/C corridor from Kavoor to Baikampady	Scenario 1	Increase in load at Baikampady substation fed by radial 110 kV S/C corridor from Kavoor substation	110 kV S/C line from Gurupura to Kavoor substations can be LILO'ed at Baikampady substation
5	110 kV D/C line from Kemar to Manipal	Scenario 1	Increase in load at Manipal, Brahmavara, Hiriyadka, Mahduvana, Kundapara and Navuda substations fed only by Kemar substation	Keeping 110 kV S/C line from Karkala substation to Hiriyadka substation (currently switched OFF) in service
6	110 kV S/C line from Sagar to Alkola	Scenario 1	Power evacuation from Linganamakki Dam Powerhouse (LDPH) and Mahatma Gandhi Hydro Electric station (MGHE)	Keeping 110 kV S/C line from MGHE to Sirsi substation in service
7	Naganathpura 2×100MVA, 220/66kV substation	Scenario 1	Increase in load at Naganathpura 220 kV substation	Addition of 3rd 100 MVA transformer at Naganathpura

Findings: Strengthening Requirement(2/2)

#	Overloaded element	Occurrence	Reason(s)	Recommendation(s)
8	Hebbal 2×100MVA, 220/66kV substation	Scenario 1	*Increase in load at Hebbal 220 kV substation*	Early commissioning of Manyata 220/66 kV substation (currently under construction)
9	110 kV S/C line from Bhutnal to Bijapur E	Scenario 2	*Low load and increase in RE capacity, requiring evacuation of power to Bijapur E substation*	Setting up a new 110 kV S/C corridor from Tikota to Bijapur E substation via Tekkalaki, Torvi and Bhutnal substations
10	110 kV S/C line from Kushtagi to Yelburga	Scenario 2	*Increase in solar generation near Yelburga substation, requiring evacuation to Kushtagi substation*	Setting up a new 110 kV S/C line from Yelburga substation to Kushtagi substation
11	110 kV S/C line from Santpur to Halabarga	Scenario 2	*Increase in solar generation at Dongargaon and Santpur substation, requiring evacuation to Halabarga substation*	Setting up a new 110 kV S/C line from Dongargaon substation to Halabarga substation via Santpur substation
12	110 kV corridor from Mundargi to Gadag	Scenario 3	*Increase in RE generation in Gadag district*	1. Upgradation of 110 kV Dambal substation to 220 kV by adding 2×100MVA transformers and connecting to Dhoni 400 kV substation through 220 kV D/C line. 2. A new 110 kV S/C line from Dambal to Mundargi. 3. A new 110 kV S/C line from VSPL to Mundargi.

Load Generation Balance for FY 2017-18

#	Particulars (Total installed capacity in MW)	Scenario 1	Scenario 1(a)	Scenario 2	Scenario 2(a)	Scenario 3	Scenario 3(a)
		State peak load	State off peak load	Peak solar	Off peak solar	Peak wind	Off peak wind
1	State hydro (3,629)	2,647	596	353	1,626	182	823
2	State thermal (7,080)	1,959	0	0	2,050	0	1,793
3	CGS –Nuclear + Thermal (3,280)	3,001	1,196	1,593	3,001	805	3,001
4	Solar (4,473)	1,610	0	4,026	0	671	1,922
5	Wind (4,602)	230	414	1,427	1,012	3,682	13
6	Co-generation (1,229)	37	61	37	37	37	47
7	Biomass (131)	3	3	12	12	4	3
8	Small Hydro (831)	33	235	17	17	133	42
9	RE total (4+5+6+7+8)	1,913	713	5,519	1,078	4,527	2,027
10	Import	4,342	3,965	3,889	4,260	3,840	3,945
Total power available (1+2+3+9+10)		13,862	6,470	11,354	12,015	9,354	11,589
11	Load	10,679	3,663	8,623	8,915	6,674	8,803
12	Export	2,724	2,724	2,424	2,724	2,424	2,453
13	Losses	459	83	307	376	256	333
Total power consumed		13,862	6,470	11,354	12,015	9,354	11,589