Explanatory note on the ongoing estimation of the transmission and distribution (T&D) losses through Karnataka's electricity system (Annexure to Karnataka's Power Sector & Suggested Ways Forward)

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Background:

This note is an Annexure to the Report on *Karnataka's Power Sector and Suggested Ways Forward* [D'Sa and Murthy, 2002]. As indicated, the losses incurred in the transmission and distribution (T&D) of electricity through Karnataka's grid have not been measured and, more importantly, have increased the cost of supply. T&D losses include both technical losses (inherent in the electrical system and higher than optimal because of the condition of the system) and commercial losses – a euphemism for theft.

The magnitude of these losses was hidden both because there has been no measurement/scrupulous estimation and because the number of unmetered consumers provided a convenient cover for these losses. T&D losses used to be merely the difference between the total (purchased plus generated) electricity and the consumers' use (both metered and apportioned). In the year 1998-99, the apportionment of un-metered electricity use between agricultural pump-sets and transmission and distribution (T&D) losses was suddenly changed, so that the proportion of pump-set use was shown to have declined (from 42.2% of the energy available for sales in '97-98 to 30.9% in '98-99) and the corresponding T&D losses increased (from 18.6% to 30.2%).

It is obviously essential that assessment of both technical and commercial T&D losses be made accurate – both for a correct estimate of the costs of supply and for assessing the feasibility of loss-reduction plans. However, this is all the more urgent because of the unbundling of the state's utilities, not only vertically between generation, transmission and distribution companies, but also the horizontal unbundling of the distribution segment of the Karnataka Power Transmission Corporation Ltd. (KPTCL) between geographical regions[1], namely the distribution companies of the erstwhile zones of Bangalore (BESCOM), Mangalore (MESCOM), Gulbarga (GESCOM), and Hubli (HESCOM).

This note is intended merely to indicate the work in progress; it outlines (1) the ***current system***, (2) the ***available estimates of technical losses*** and the required ***capital investment*** for reducing these in the light of three growth scenarios, and (3) further work required.

1. Status of Karnataka's State Transmission and Distribution (T&D) System (on 1st April 2001):

1(a) Transmission:

Total transmission network in circuit kilometres (ckm) at each voltage level:

HT/EHT Lines	Length (ckm)
400 kV	1,149.3
220 kV	7,951.1
110 kV	6,512.8
66 kV	5,845.3

[1] This -- the most recent landmark in the power sector "reform" process – took place in June 2002.

33 kV	6,536.2
Total	27,995.0

Source: KPTCL's web-page www.kptcl.com

Poor voltages are prevalent at most of the busses of the transmission system, and most parts of the state. Many of the transmission lines including the evacuation lines are overloaded beyond surge impedance loading capacities. Many of the power transformers are also over loaded. The system is operating without any provision for contingencies such as line outages, which result in system breakdowns.

Given the enormity of the problem, consultants were entrusted with the task of estimating transmission and distribution losses. According to their reports [Mecon, 2001], the transmission losses were as follows:

Transmission loss assessment from 400 kV line to 11 kV line (1998-99)

Description	**Electricity (in GWh)**	**Losses as % of total electricity input**
Energy input at the 400 kV bus	7787	
Loss in 400 kV line	40	
Availability at 400 kV line	7747	
400 kV to 220 kV transformation loss	7	
Available at 220 kV line from 400 kV line	7740	
Total loss at 400 kV system	**47**	**0.21**
Energy input at 220 kV line	13721	
Wheeled to Kerala and Goa	721	
Sub total	20740	
Loss in 220 kV system	**1144**	**5.03**
Energy input at 110 kV line (110/33 kV, 100/11 kV)	1008	
Energy transferred from higher voltages	8431	
Total energy available at 110 kV	9439	
Energy loss in 110 kV system	**277**	**1.22**
Energy input at 66 kV system (66/11 kV)	945	
Energy transferred from higher voltages	10500	
Total energy available at 66 kV	11445	
Energy loss in 66 kV system	**901**	**3.96**
Energy input at 33 kV line (33/11 kV)	4	
Energy transferred from higher voltage	4303	
Total energy available at 33 kV	4307	
Energy loss at 33 kV system	**206**	**0.91**
Energy input at 11 kV line (33/11 kV)	2	
Energy transferred from higher voltage	18629	
Total energy available at 11 kV	18631	
Energy loss at 11 kV system		
Total energy input to KPTCL system	**22746**	**11.33**

Source: Mecon, 2001.

1(b) Distribution:

Total distribution network at each voltage level:

HT/LT	Length (ckm)
HT Lines	128,798
LT Lines	357,017

- Number of distribution transformers =148,099
- Number of capacitor banks = 3,362 MVAR
- Number of substations = 684

Source: KPTCL's web-page www.kptcl.com

The distribution network including 11 kV lines has been overloaded in most areas. Most of the distribution transformer centres are also over loaded. There have been numerous problems in the estimation of losses through the distribution system [Mecon, 2001]; nevertheless, in the absence of more accurate estimates, these are presented:

Estimated losses in the distribution network (at all voltage levels) during 1998-99

Consumer category	**Electricity loss (GWh)**
LT	
Bhagya Jyothi*	301
Domestic lighting	1,425
All Electric Homes	1,616
Commercial	580
IP sets below 10 HP#	6,130
IP sets above 10 HP	16
Water supply – village & town	164
Water supply – CMCs	45
Water supply – private layouts	3
Water supply – private plantations	3
Industrial	1,181
Public Lighting (villages & towns)**	71
Public Lighting – others**	90
Temporary supply	28
Sub total (LT)	11,653
HT	
Public Water supply	547
HT industries – 11 kV	827
HT industries – 33 kV	114
HT industries – 66 kV	482
Sale to APSEB	7
HT industries – 110 kV	277
HT industries – 220 kV	637
Commercial	285
Irrigation	41
Rural co-operative societies	106
Temporary supply	12

Railway traction	28
Residential apartments	31
Sub total (HT)	3,394
Total	15,047
Energy input for KPTCL use	22,746
Total energy loss	7,699
Total Energy Loss (as % of supply)	**33.85**
Of this, distribution losses =	**22.52**

Source: Mecon, 2001.
Basis of estimation of unmetered supply (with asterisks):
* Bhagya jyothi estimation is based on the assumption of 100 watt/consumer and used 6 hours/day.
# Irrigation pump-set (ipset) estimation is based on the average of recorded figures at the transformer centres with a load factor of less that 0.75.
** Public supply estimation is based on the connected load and 12 hours/day utilisation.

When filing their annual petition for change of tariffs and expected revenue from charges (ERC) with the Karnataka Electricity Regulatory Commission (KERC), the KPTCL describes its own estimates of T&D losses. Their provisional energy flow diagram for the year 2001-02 [KPTCL, 2002] -- indicating total losses of 9,515 GWh out of 28,408 GWH purchased/generated (33.5%) -- is replicated in Annexure 1 (p.12).

2. Capital required for system improvement:

Thus far, the only available estimates of the investment required for KPTCL's system improvement are from KPTCL itself [Guptha, 2001][2]. These estimates were made, considering growth in demand for power as envisaged in three scenarios, namely, the projections of the Sixteenth Electric Power Survey (16th EPS) of the Central Electricity Authority [CEA, 2001], the business-as-usual projection (at the rate of 6.3% prevailing during '90-2000) and that of the Financial Reconstruction Plan (FRP) of the KPTCL.

Summary of the capital investment (in Rs crore[3]) required between 2001-02 and 2011-12:

	Details:	16th EPS load growth 10,460 MW (by 2011-12)	6.3% load growth 8741 MW (by 2011-12)	FRP Load growth 6341 MW (by 2011-12)
1	Transmission	6,652	5,532	3,320
2	Distribution	5,100	4,500	3,600
3	**Total**	**11,752**	**10,032**	**6,920**

[2] The details provided in this section have been taken from this source.
[3] Crore = 10^7

4	T&D Losses during 2000-01	29 %	29 %	29 %
5	Expected T&D losses during 2011-12	14.35 %	14.32 %	14.86 %
6	Reduction of T&D losses	14.65 %	14.68 %	14.14 %
7	Capital requirement for reduction of 1% T&D loss	802	683	490

The derivation of the above figures is now being explained in sub-sections (a) and (b), for the transmission and distribution systems, respectively.

2(a) Transmission system:

The estimates of the total transmission losses in the system in the past three years are as follows:

Loss computation year		**1998-1999**		**1999-2000**			**2000-2001**			
Peak demand in MW		3,820		3,985			4,464			
Total energy for the year (in GWh)		22,736		26,116			27,701			
Peak power losses and energy losses	**Voltage class**	**Peak power losses in MWs**	**Energy losses**	**Peak power losses in MWs**		**Energy losses**	**Peak power losses in MWs**		**Energy losses**	
			in GWh	% losses		in GWh	% losses		in GWh	% losses
	400KV	29.27	135.19	0.59	34.53	186.38	0.71	32.94	161.35	0.58
	220KV	183.08	845.13	3.72	215.63	1164.00	4.46	196.98	964.74	3.48
	110KV	47.71	220.23	0.97	40.59	219.10	0.84	44.99	220.34	0.80
	66KV	68.46	316.02	1.39	77.45	418.10	1.60	79.26	388.19	1.40
	33 KV	141.39	652.68	2.87	87.35	471.53	1.81	123.34	604.07	2.18
	Transformer losses (GWh)	35.18	162.41	0.71	19.59	171.60	0.66	20.58	180.27	0.65
Total peak power and energy losses in the transmission system		505.09	2331.66	**10.26**	475.14	2630.71	**10.07**	498.09	2518.96	**9.09**

There was a short fall of about 862 MW between availability & unrestricted demand for the year 2000-01, amounting to about 16%. Hence scheduled & unscheduled load shedding were resorted to.

Load flow studies for the transmission network were conducted for all the three load projection scenarios till the year 2011-12.

Annual projections of power and energy demand for the planning period, according to the three scenarios:

	Year	*16th EPS MW	*16th EPS GWh	**FRP MWs	**FRP GWh	***6.3 % growth MW	***6.3% growth GWh
1	00-01	5326	30791	4368	27517	4464	27701
2	01-02	5699	32950	4506	28387	4746	29086
3	02-03	6068	35084	4651	29303	5044	30540
4	03-04	6440	37235	4804	30266	5362	32067
5	04-05	6826	39467	4965	31280	5700	33671
6	05-06	7283	41635	5134	32347	6059	35354
7	**06-07**	**7740**	**44345**	**5312**	**33470**	**6441**	**37122**
8	07-08	8237	47009	5500	34652	6846	38978
9	08-09	8753	49823	5698	35896	7278	40927
10	09-10	9285	52816	5906	37207	7736	42973
11	10-11						
12	**11-12**	**10460**		**6314**		**8741**	

Please note:

* CEA 16th Electric Power Survey Projections are for un-restricted conditions.

** F.R.P projections consider about 3.0 % annual growth.

*** A supply shortage of 16% (vis-à-vis the business-as-usual scenario with a 6.3% annual growth) appears to be continuing.

The figures in bold font correspond to the horizon years of the Five-Year Plans. Estimates for the 11th year were left blank in the original source.

The capital requirement includes investment in distribution transformers to cut down losses, and investment in additional sub-stations and capacitor banks.

The capital investment corresponding to reduction in transmission losses during the eleven-year period from 2001-02 to 2011-12:

	Scenario	Projected Peak Load (in MW) for 2011-12	Capital expenditure requirement from 2001-02 to 2011-12 (Rs crore)	% transmission losses during the year 2000-01	% transmission losses during the year 2011-12
1	FRP	6,314	3,320	9.09	4.86
2	at 6.3 % growth	8,741	5,538	9.09	4.32
3	16th EPS	10,460	6,652	9.09	4.35

Please note: The investment in the strengthening of the Southern grid by the Power Grid Corporation of India Limited (PGCIL) has not been included, as Karnataka has to bear only the transmission charges for this work.

2(b) Distribution system:

The distribution system comprising 11kV lines, LT 400V lines, of about 1,28,419 km and 3,52,377 km, respectively, and 143,382 distribution transformer centres (DTCs), has not been studied completely. However, some general observations can be made.

- The 11 kV feeders are mostly overloaded. Sample studies of a few feeders reveal that percentage voltage regulations are far beyond the permissible limits, which has resulted in low voltage conditions and high line losses.
- The LT 400 V lines too are overloaded and most of the lines are with number 4 squirrel ACSR conductors. The sample studies also reveal poor voltage conditions and high line losses.
- The existing distribution transformer centres (DTCs) too are either loaded fully or even overloaded. Most of the DTCs are not situated at the actual load centres, since location of the DTCs at the time of installation was decided on the loading conditions prevailing at the time and further extension of LT lines and additional loads contributed to overloading and lengthy LT lines.
- The low tension to high tension (LT to HT ratio) of the distribution system is about 2.74:1, against the accepted norms of 1:1. This has resulted in poor voltage levels, high distribution losses, unreliable power supply and high failure rates of DTCs. It is required that the 11 kV HT lines be extended to an extent of about 2,08,995 of 11 kV lines to bring the ratio to 1:1. This will cost about Rs 2,090 crores, in addition to providing additional DTCs.
- An analysis of the distribution network (both 11 kV lines and LT lines) pertaining to about 120 feeders spread over all the regions of the state was conducted during the year 1998 under demand side load management (DSLM) programme. Methods were worked out to improve the distribution network of these 120 feeders and cost estimates were prepared. The approximate cost for improving the distribution system per 11 kV feeder was about Rs 1 crore.
- A study of 11 kV lines in the Kolar and Tumkur[4] circles has been conducted by KPTCL, Bangalore. The details are as follows:

	Name of the Circle	**Number of feeders in the Circle**	**Number of feeders analysed**	**Total cost for improvement of 11 kV lines (in Rs lakh)[5]**	**Cost per feeder (in Rs lakh)**
1.	Kolar	242	229	5,220	22.79
2.	Tumkur	250	225	5,734	25.48
	Total	492	454	10,954	24.12

- The average number of DTC's per 11 kV feeder in the state is about 38. Sample analyses have indicated that the present number of DTC's should be doubled to bring the system to normal/ideal conditions, i.e. to have reliable/quality power

[4] These are two districts in the Bangalore zone of Karnataka; they are now a part of BESCOM.
[5] Lakh = 10^5

supply and to reduce distribution losses. The cost of establishing the additional 38 transformer centres per feeder will be approximately Rs 76 lakhs at the rate of Rs 2 lakh per DTC including providing DTC, and associated HT, LT lines, energy meters, etc.

- Proposals were made for improvement of the distribution network in four circles -- Mysore, Belgaum, Bijapur, & Hubli -- as short term measure under the World Bank funded Accelerated Power Development Programme (APDP) -- at a cost of Rs 350. The total expenditure for all the 14 circles will be about Rs 2,450 crores.

Approximate cost of improving the distribution network:

- The distribution system in areas where irrigation pumpset loads are concentrated has deteriorated to a great extent due to the steep increase of agricultural load during last two decades[6]. The agricultural loads are concentrated mainly in Kolar, Tumkur, Bangalore-Rural, Davanagere, Belgaum, Bijapur, Munirabad Circles and Chamarajanagar District. For the remaining areas it may be sufficient to take up less extensive improvement and distribution-expansion programmes, at about Rs 0.50 crore per 11kV feeder.

- The total number of 11 kV feeders in the state (as on 31/3/2001) was 3,727. The number of 11 kV feeders in the above mentioned agricultural-load-concentrated areas are 1541. The details are as follows:

Kolar circle	242 feeders
Tumkur circle	250 feeders
Bangalore rural circle	143 feeders
Davanagere circle	282 feeders
Belgaum circle	301 feeders
Bijapur circle	231 feeders
Munirabad circle	182 feeders
Chamarajanagar District	90 feeders
Total	1721 feeders

- The capital investment required for improving distribution system of a one 11 kV feeder, in a load concentrated area would be about Rs1 crore, according to the DSLM study.
- The capital investment required for improving distribution system of a one 11 kV feeder, other than the load concentrated area would be about Rs 0.5 crore.

- The capital investment required for distribution system expansion per 11 kV feeder to meet the different load growths will be approximately as follows:

[6] Agricultural pumpsets were de-metered in 1982-83.

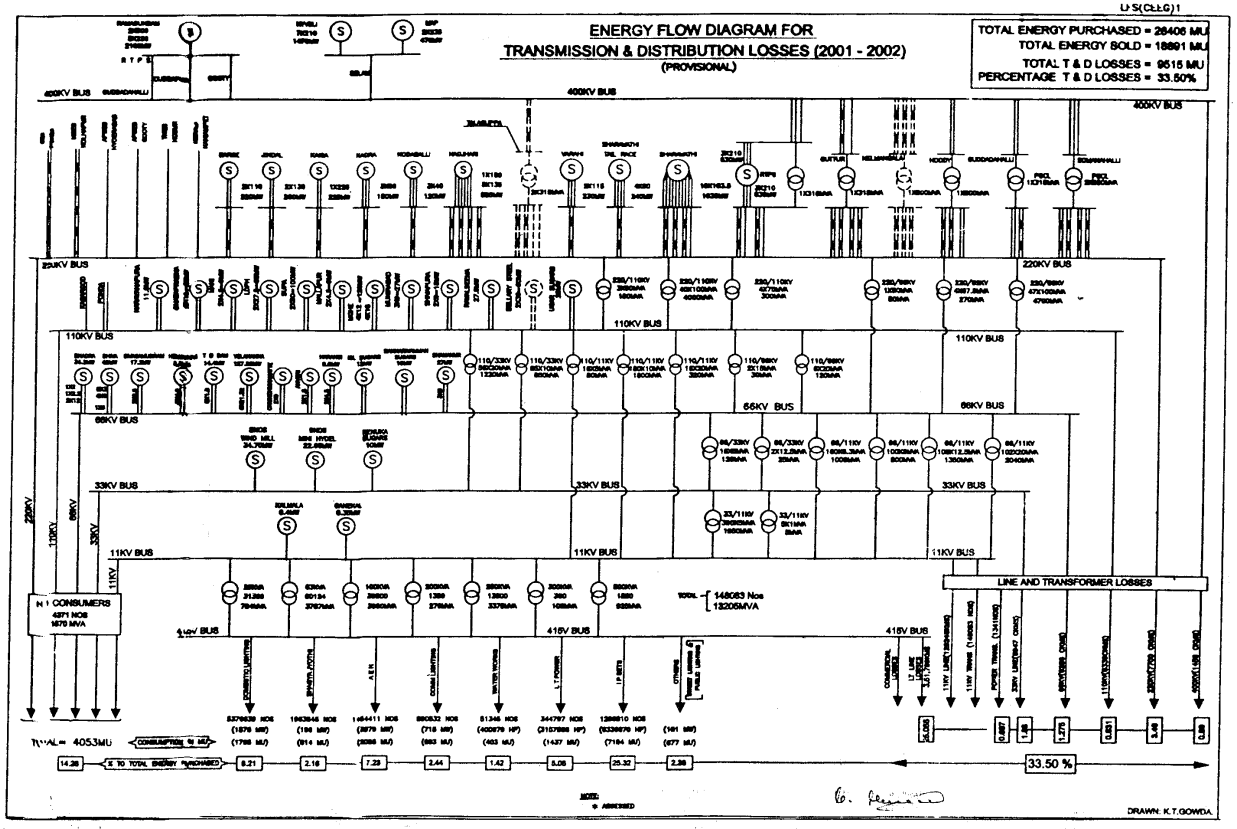
(1) For 16th EPS load growth: Rs 2,500 crore (at the rate of Rs 6 lakh per year per feeder).
(2) For 6.3 % load growth: Rs 1,900 crore (at Rs 4 lakh per feeder per year).
(3) For FRP (~ 3%) load growth: Rs 1,000 crores (at Rs 2.5 lakh per year)

3. Work to be done:

There still remains much to be done on the estimation of the system losses. This has been hampered by data limitations and the absence of adequate field studies. Broadly, the work will required:

- Metering of all connections – particularly irrigation pump-sets, as estimates on the basis of sample may be biased;
- a far more rigorous assessment of the present losses through the distribution system;
- with respect to T&D loss reduction through system improvement, again, more elaborate estimation has to be conducted (as the studies made so far have been inconclusive).

A detailed report will be prepared after this information is collected.


ENERGY FLOW DIAGRAM FOR
TRANSMISSION & DISTRIBUTION LOSSES (2001 - 2002)
(PROVISIONAL)
TOTAL ENERGY PURCHASED = 28406 MU
TOTAL ENERGY SOLD = 18891 MU
TOTAL T & D LOSSES = 9515 MU
PERCENTAGE T & D LOSSES = 33.50%
400KV BUS
220KV BUS
110KV BUS
66KV BUS
33KV BUS
11KV BUS
415V BUS
LINE AND TRANSFORMER LOSSES
33.50 %
DRAWN: K.T.GOWDA

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