Effects of unbalanced loading on network losses in Pakistan

Damage to power system economics

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Introduction

Technical Losses

- Copper losses
- Dielectric losses
- Induction & radiation losses

Causes

- Harmonics distortion
- Improper earthing
- Unbalanced loading
- Overloading and low voltage
- Poor standards

Non-technical Losses

- Meter tampering
- Computational errors
- Energy stealing
- No bill payment
- False readings
- Taps on L.T lines

Introduction

Unbalance Loading

- Mostly distribution loads are single phase
- Current flows through neutral
- Zero & Negative sequence currents flow
- Superposition of $V2$ & $V0$ causes angle deviation
- Superposition of $I2$ & $I0$ lead to increased current

Actions

- Redistribution of loads
- Use of inductive & capacitive circuits
- Use of phase shifting transformer
- Circuits should also supply reactive power

Case Study

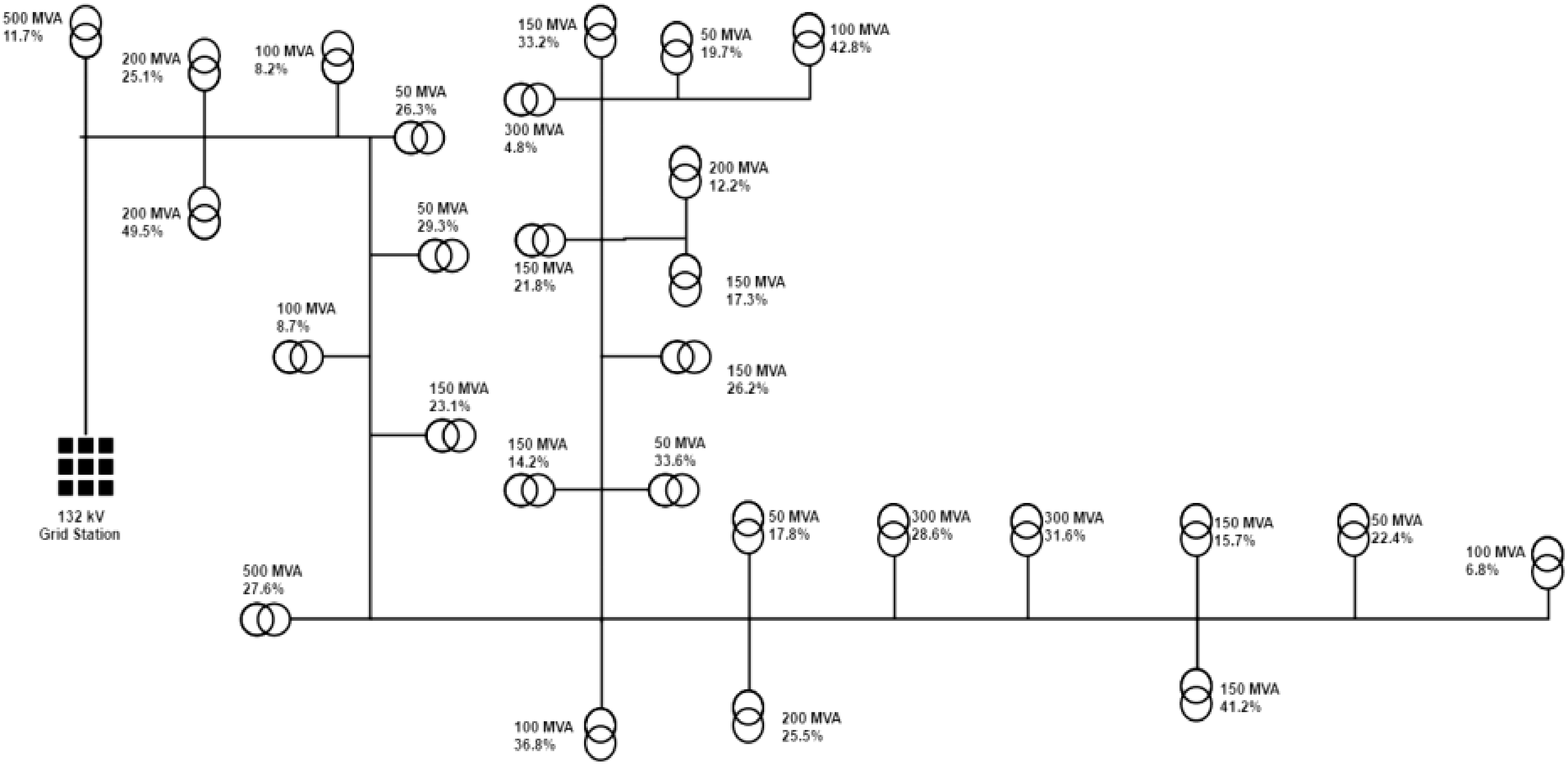


Fig. 1. 11 kV Dhari Distribution Feeder from 132 kV Larkana Grid Station

Case Study

TABLE 1. TRANSFOMERS' RATINGS FOR 11 KV DHARI FEEDER of SEPCO GRID STATON

Quantity	Transformer's Rating (KVA)	Total Capacity (KVA)
6	50	300
5	100	500
8	150	1200
4	200	800
3	300	900
2	500	1000
	Total	4700

$$P_{Loss} = P_{Suppled} - P_{Bill} \quad (1)$$

$$\Delta E_T = \Delta E_{NL} + \Delta E_L \quad \text{kWh} \quad (2)$$

$$\Delta E_{NL} = \Delta W_{NL} \times T \times 10^{-3} \quad \text{kWh} \quad (3)$$

$$\Delta E = \frac{[\{(E_P^2 + E_Q^2) \times k_f^2\} \times R_{EQ}]}{[V_{EQ}^2 \times T]} \quad (4)$$

$$\Delta E_L = 1.63\left(\frac{E_P^2}{V_{norm} \times T}\right) R_{EQ} \quad \text{kWh} \quad (5)$$

$$R_{EQ} = \frac{r_0 \times l}{1000} \quad \text{ohms} \quad (6)$$

$$\partial E = \Delta E(\mathrm{K}_{j1} - \mathrm{K}_{j2}) \quad \text{kWh} \quad (7)$$

$$\mathrm{K}_j = [3 \times (\frac{\mathrm{I}_A^2 + \mathrm{I}_B^2 + \mathrm{I}_C^2}{\mathrm{I}_A + \mathrm{I}_B + \mathrm{I}_C})] \times (l + 1.5 \times \frac{R_0}{R_{PH}}) - (1.5 \times \frac{R_0}{R_{PH}}) \quad (8)$$

Case Study

For lines with $\frac{R_0}{R_{PH}} = 1 \quad K_j = 1.13$

For lines with $\frac{R_0}{R_{PH}} = 2 \quad K_j = 1.2$

$$I_{avg} = \frac{(I_A + I_B + I_C)}{3} \qquad (9)$$

$$I_D = \begin{vmatrix} I_A - I_{avg} \\ I_B - I_{avg} \\ I_C - I_{avg} \end{vmatrix} \qquad (10)$$

$$\%I_{imbal} = \frac{\max(I_D) \times 100}{I_{avg}} \qquad (11)$$

TABLE II
POWER LOSS CALCULATIONFORIMBALANCEDANDBALANCED LOADNGS
ON 11 kV DHARIFEEDER, SEPCO NETWORK

TRANSFOMER			POWER LOSS (kW)		
Serial No.	**KVA Rating**	**$\%I_{imbal}$**	K_{j1}	K_{j2}	K_{j1}-K_{j2}
1	100	36.8%	2.32	1.81	0.51
2	200	25.1%	12.35	11.17	1.18
3	200	49.5%	7.85	7.11	0.74
4	100	8.2%	5.26	3.67	1.59
5	50	26.3%	17.31	15.23	2.08
6	50	29.3%	5.85	3.22	2.63
7	100	8.7%	11.47	9.68	1.79
8	150	23.1%	19.57	15.77	3.8
9	150	14.2%	11.48	9.87	1.61
10	150	21.8%	7.64	2.67	4.97
11	300	4.8%	15.64	13.91	1.73
12	150	33.2%	16.3	13.7	2.6
13	50	19.7%	3.4	1.8	1.6
14	100	42.8%	5.7	3.8	1.9
15	200	12.2%	8.87	6.14	2.73
16	150	17.3%	6.78	2.54	4.24
17	150	26.2%	13.98	11.23	2.75
18	50	33.6%	3.56	2.78	0.78
19	50	17.8%	1.23	1.02	0.21
20	200	25.5%	4.65	3.32	1.33
21	300	28.6%	13.67	11.51	2.16
22	300	31.6%	19.56	15.45	4.11
23	150	15.7%	8.57	5.64	2.93
24	150	41.2%	6.37	3.73	2.64
25	50	22.4%	0.87	0.34	0.53
26	500	27.6%	23.47	20.78	2.69
27	100	6.8%	8.72	6.83	1.89
28	500	11.7%	21.45	17.57	3.88
	Total		283.89	222.29	61.6

Case Study

- Economic Effects

$$P_{LT} = \sum K_{j1} - \sum K_{j2} \quad (12)$$

P_{LT} = (283.89-222.29) = 61.6 kW

$$P_{HT} = I^2 \times (\frac{\rho \times l}{A}) = 5.89 \text{ kW} \quad (13)$$

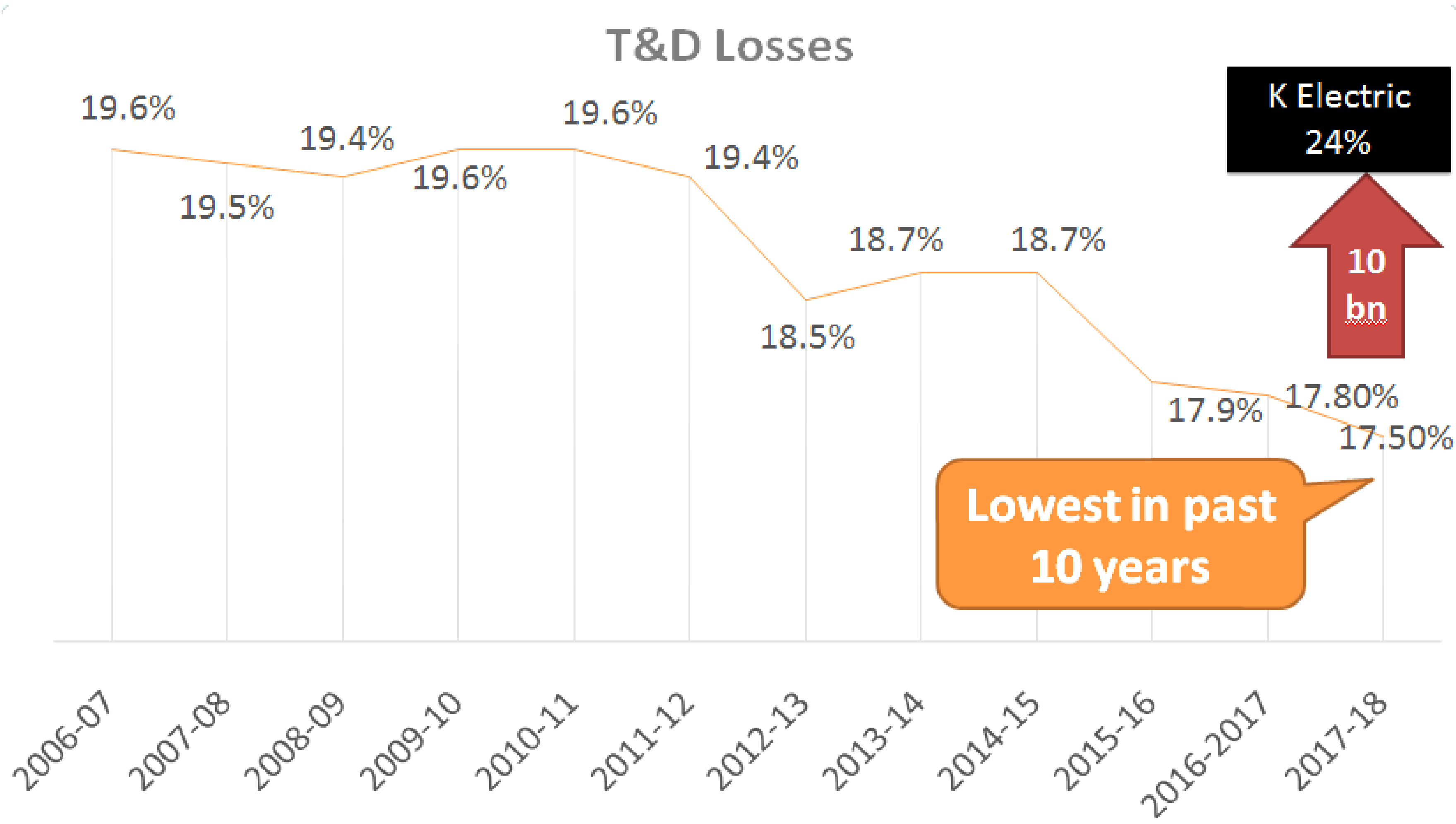
$$W = P_{LT} + P_{HT} \quad (14)$$

W = 61.6 + 5.89 = 67.49 kW

TABLEIII
ECONOMC EFFECT OUTCOME WITH COST RECOVERY PEROD FOR DFFERENT TRANSFORMER BAYS

Transformer (KVA)	Same Rated Transformers Quantity	Cumulative Consumers	Reduction of power loss after implementing proposed method in (kW)	Saving after implementing balancing proposed method in (Million Rs.)	Expenditure for Implementing method in (Million Rs.)	Time for total cost recovery (Months)
50	6	69	7.83	0.3341	0.1013	4
100	5	113	7.68	0.3277	0.0993	4
150	8	218	25.54	1.0889	0.3301	4
200	4	137	5.98	0.2552	0.0773	4
300	3	189	8	0.3414	0.1035	4
500	2	195	6.57	0.2803	0.0849	4

Facts & Figures



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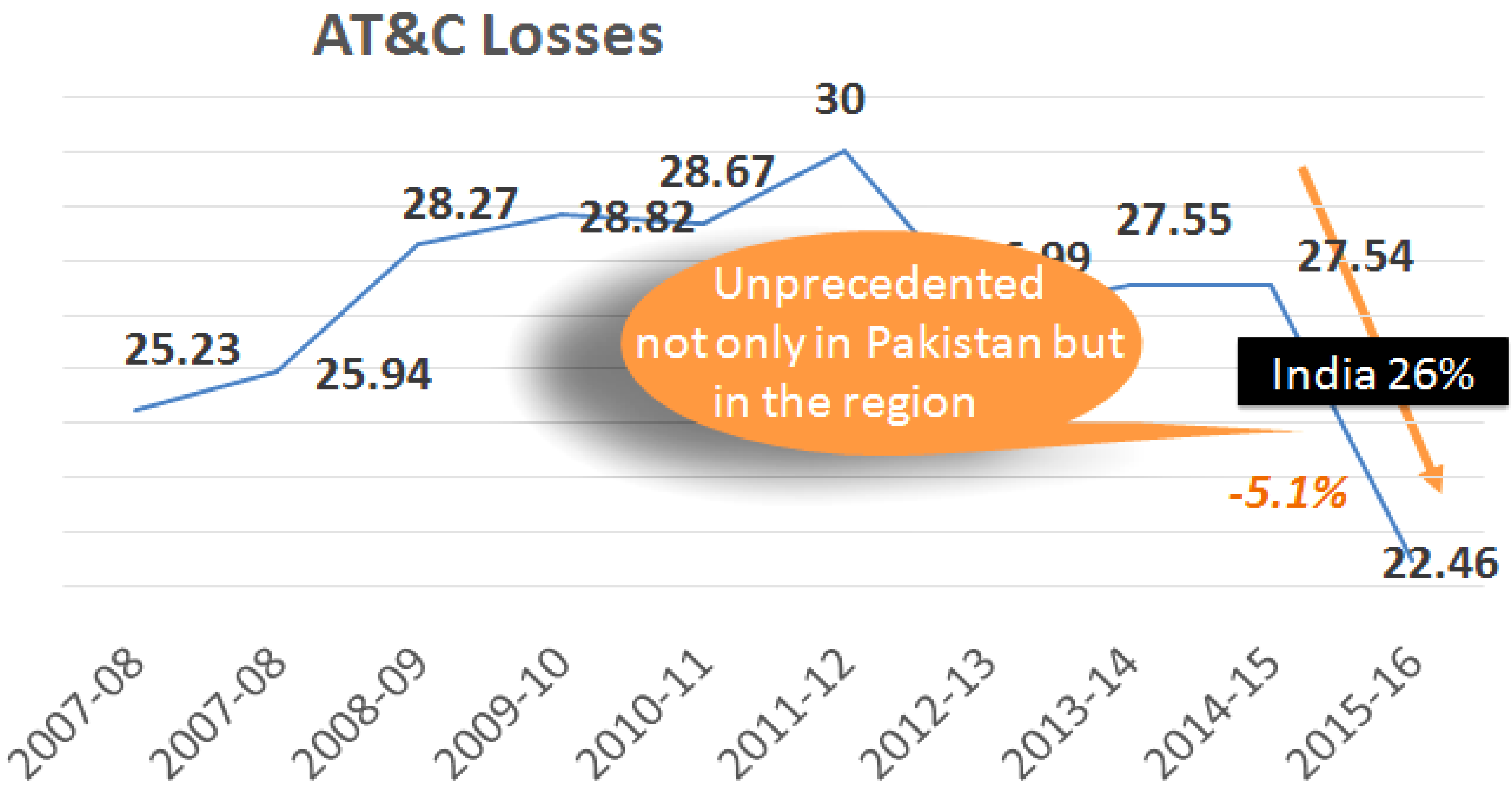

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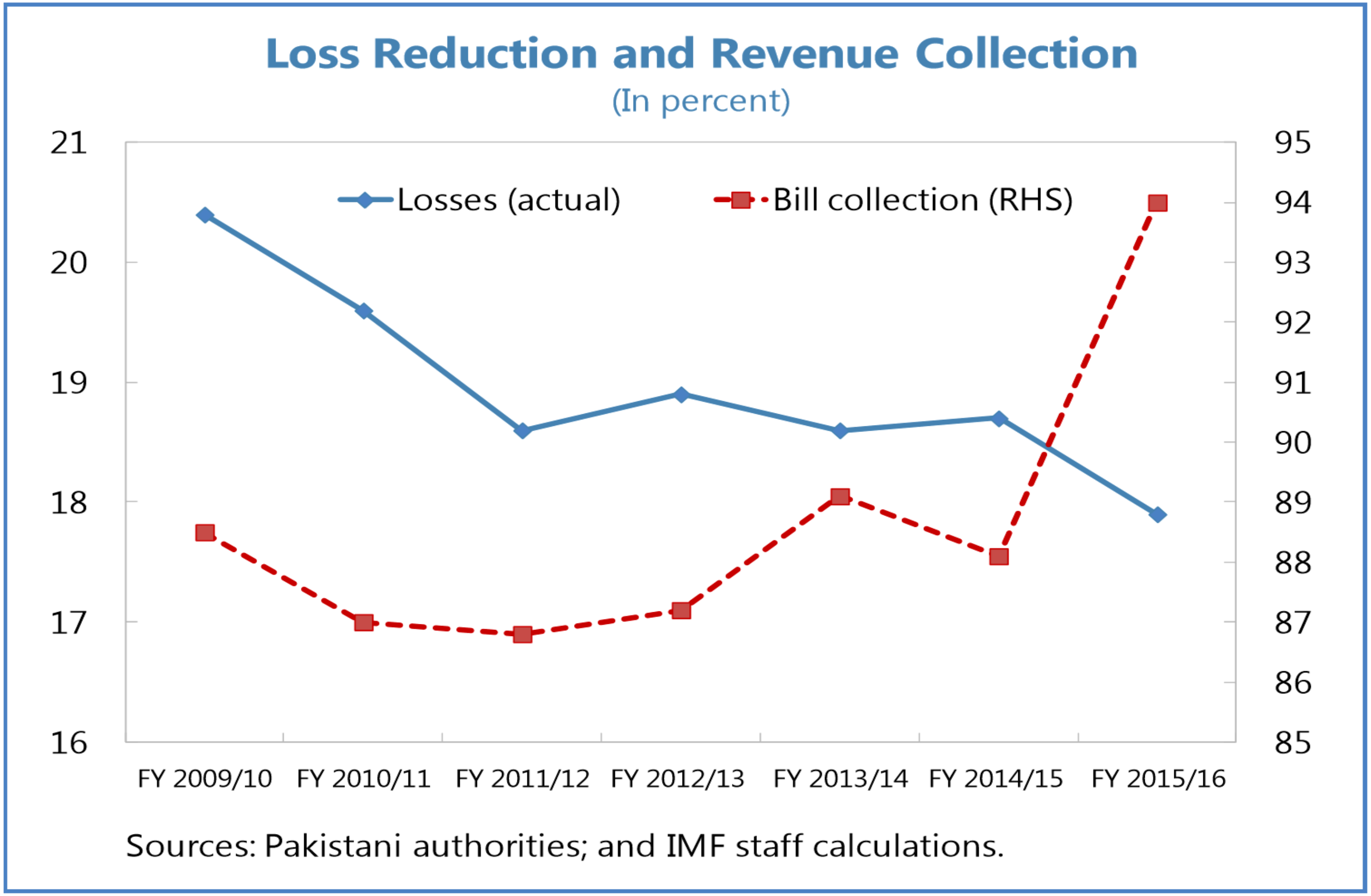

Remedies

- Bringing end-to-end transparency through digital interventions:
  - Bringing in components of a Smart Grid
  - SCADA based National Grid from Generation to DISCOs
  - Smart Metering in DISCOs up to consumer level
- ERP based operational and financial monitoring systems
- Realistic Cost-recovering Tariff Regime
- Subsidy rationalisation on RES

Queries???