Power Sector Reform
India – The Long Road Ahead

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Outline

- Overview of the Indian power sector
  - Structure
  - Performance
    - Drivers for reform
- Reform steps
  - Mechanisms and modes
- Analysis
- Conclusions
<table>
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<td>Uttar Pradesh</td>
<td>174.5</td>
<td>517</td>
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<td>349.2</td>
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<td>152.4</td>
<td>65.4</td>
<td>15,735</td>
<td>359.6</td>
<td>2.9</td>
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</table>

**Bihar includes Jharkhand for some data**
*Uttar Pradesh includes Uttaranchal for some data

*Calculated and compiled from various official sources*
Pre-Reform (1991) Structure

- SEBs (State Electricity Boards) were responsible for power supply
  - Govt. Departments
  - Vertically integrated monopolies
    - Most of the Distribution
    - Much of the Transmission
    - Significant fraction of the Generation
  - Supposed to earn 3% RoR on Asset Base

Source: Dubash (2002)
Indian Power Scenario - Overview

- Installed Capacity ≈ 105,000 MW
  - 1,500 MW in 1950
  - 4th largest in the world (estimate – varies because of captive power)
  - Coal is the predominant fuel
  - Gross generation of 515 billion kWh in 2001-02

- Per capita consumption ≈ 360 kWh
  - World Average ≈ 2,200 kWh

- 90% villages electrified
  - BUT, < 40% of rural houses connected

- 10,000 - 15,000 MW annual growth needed
Not Enough Paying Consumers: Mismatch in Consumption & Tariffs (2001-02)

Consumption ≈ 315 Billion kWh

Prices
239.9 ps/kWh (Average)
≈ 5.00 ¢/kWh

Source: Planning Commission
The Bottom Line

- “Cost of supply” is Rs. 3.50/kWh, realization only Rs. 2.40/kWh
  - Much of the electricity is sold below cost (and some well above cost)
  - Much of it is unaccounted for
    - High T&D losses (~30%)  US losses are 8-9% only
      - Technical – 12-15% (?)
      - “Commercial” =Theft – 15-18%

- Utilities are bleeding money
  - Returns calculated as –30 to –40%
  - Losses (excluding $1.5 B subsidy) are approximately $4 billion
Utilities Pay for Politics of Agricultural Tariff

- Agriculture: 30% consumption; < 5% revenues
  - Industry bears the brunt – cross subsidy
    - They move to captive power, hurting the current system more

- Subsidies are growing
  - Not completely covered by tariff increases, government subsidy & cross subsidy

- Irrigation pumps not metered
  - Wasteful consumption
  - Inefficient pumps
  - Illegal connections

- Intermittent & poor quality supply: 6 – 9* hours/day
  - Farmers may be willing to pay for regular & good quality power
The Reforms

Opening up Generation (1991)

- Paralleled overall reforms and liberalization in the economy
  - Triggered by a Balance of Payment Crisis
  - Change of Central Government
- Generation was opened to private participation
  - 8 “Fast Track Projects” were chosen, including Enron’s Dabhol
  - IPPs encouraged through attractive norms
  - PPA-based tariffs (often, no bidding)
  - Main regulation was through CEA (techno-economic clearance)
- Why the focus on generation?
  - Easy to implement (states already had “outside” suppliers)
  - Worldwide trend
    - Players and structure (rise of IPPs)
    - Rise of natural gas combined cycle power plants
- Limited capacity added
  - Private power was much more expensive than SEBs own power
The Reforms (cont.)

- **Structural Changes (mid 1990s)**
  - Establishment of independent Electricity Regulatory Commissions
  - Came, like most changes, under legislative cover
  - Intent to unbundle the SEBs
  - Some states began in the mid nineties; Center reformed in 1998
    - Began even before realization of shortcomings of generation reforms
    - Significant push from Multi-Lateral Agencies

- **Distribution Reforms (APDRP) (2001) Current Thrust**
  - Consensus realization that without fixing distribution, all other reforms will “throw good money after bad”
  - Significant funding available
    - About $1.5 Billions dollars per year - Mix of grant and loan, and some domestic development body funding
  - Combination of carrots and sticks (from Center to States)
PSUs, Government, and ERCs

Source: CERC
Electricity Regulatory Commissions (ERCs)

- Are key to the reforms
  - Set tariffs (bulk supply as well as retail)
    - Separates price-setting from operations
    - Any tariff-driven shortfall must be met through explicit government payments
- Central and State ERCs
  - States’ purview is for all purely in-state transactions
  - Diminishing the role of the CEA to technical approvals
- ERCs are reasonably independent
  - Minimum 55 years age requirement – Commission members often have a govt. background
    - (?) a negative as it perpetuates business-as-usual mentalities
ERCs (cont.)

- Utilities attempt to ignore their orders
  - Often are challenged in court
    - Especially by govt. bodies or SEBs
    - Have won virtually all their cases
- Their Tariff Philosophy remains important
  - Have disallowed large hikes for some classes of consumers
  - Make (sometimes untenable) assumptions
    - E.g. on simultaneity of loads
- Aggressively pushing for loss reduction
Modes of Structural Reform

- Most restructuring is through unbundling and corporatization of the SEBs
  - GenCo
  - TransCo
  - Single Buyer
  - DistCos
    - Based on geography
- End-game is privatization (sequential reform is perhaps politically easier)
- Many models of reform available
  - Reforms do not necessarily mean markets
  - Where would competition come in?
    - Generation (wholesale competition) – limited success
    - No retail competition
    - Auctions for privatizing distribution companies (or other assets)
State Reforms – Three Examples

- Orissa – The Front Runner (1996 Reform Act)
  - Unbundled and then privatized distribution
    - Strong World Bank influence (design and finance)
  - Considered a failure - Consumers and utilities have both suffered
    - Losses (kWh and economic) both increased
  - Many causes of failure
    - Unrealistic assumptions and goals
      - Losses
      - Paying Customers
    - Lack of government support
  - Dampened enthusiasm for reforms, especially privatization
State Reforms (cont.)

- Andhra Pradesh – Seen as one of the most successful reformers (1999 Reform Act)
  - Corporatization only (privatization is some time away)
  - Strong Govt. support
    - Shortfalls are paid by AP Govt. (budget) – paid out to DistCos
  - Some issues with the process
    - ERC allows Transco to charge varying Bulk Supply Tariffs to the 4 DistCos, based on their economic situation
      - Not grounded in economic efficiency
      - Burdens privatization efforts

- Delhi – Innovative - Learning from past mistakes (2000 Act)
  - Distribution was privatized (in 2002) based on loss reduction bids
    - Improvements above targets split between pvt. companies and consumers
    - Indicates importance of **benchmarking** for privatization
  - Transco will receive the subsidy to cover difference
Unbundling – Increases Accounting Transparency

Present (est.)

Future (hypothetical)

Unbundling “forces” profitability – raising costs
What Reforms Don’t Address Directly

An institutional framework for economic success, regardless of ownership/mode, must send correct price signals

- Virtually no time-of-day prices today (generator or consumer)
  - Without a load duration curve, all generators want to operate as much as they can
    - Plant load factor is a dangerous measure of performance
- In-state (SEB) plant is today priced differently
  - Internally see marginal costs vs. Average costs from outside
  - Different regulations (center vs. State ERCs)
- RLDCs vs. Transco – how should dispatch be handled?
  - PPAs as currently being undertaken reduce economic efficiency
    - Long life
    - High offtake requirements
    - No accounting for variable costs
What Reforms Don’t Address Directly/Completely (cont.)

- Use of average numbers masks information about marginal costs – important for efficiency
- Access – not just a supply issue but demand (affordability)
- Agriculture – how can the prices be rationalized?
Issues for Reforms

- Utilities still don’t function like business entities
  - SEBs used for political patronage, social engineering
  - Part of the privatization process included “deals with the devil” over labor security
    - High employee costs, perhaps greater institutional cost
    - Andhra Pradesh has over 65,000 employees for about 6,200 MW
      - Connecticut has just a several thousand employees for similar capacity!

- In a loss-making system, who has first rights to cash flow?
  - Earlier policies favored generators over other segments
  - What of cherry picking for privatization (viable, urban areas)?

- Are there enough players, and does size matter?
Future Reforms

- A Big Bang Approach?
  - Pending Electricity Bill 2001 might alter things drastically
    - Open access philosophy
    - Helps private players and some consumers, might hurt the SEBs/current utilities

- Successful reforms will depend on political will to tackle the hard issues facing the sector
Points for Discussion and Research

- Grid design
  - Signals, stakeholders, and policy
  - ABT – Availability Based Tariff
- IT and innovation
Conventional Wisdom

- One can not do real-time power flow management (transactions and billing) for transmission level flows
  - Today, pools often operate based on historical or aggregated information
- One can not measure demand (usage) from all consumers in real-time with high granularity

What has changed to make these outdated – the growth of IT technology
Idea – use IT for power sector management

- Posit – If new meters are to be installed, why not “smart” digital meters, which are also controllable, and communications-enabled?
  - Incremental costs would be low
- Instead of just quantity of power, can also improve quality of power
- Analysis presented is based on collaborative work with a major utility in India (name withheld for confidentiality reasons)
Quality of Power

- India is focusing on quantity of power only
  - Current “shortfall” numbers are contrived
    - Based only on loadshedding with minor correction for frequency
    - Do no factor in peak clipping fully
    - Do not account for lack of access (e.g., over 60% of rural homes lack connections)
  - Quality norms are often missed
    - Voltage – often deviates by 25+% 
    - Frequency – often deviates by 5% (!)
  - Even farmers pay a lot for their bad quality power
    (around 50 p/kWh implicit, even higher in some regions)
  - Use of voltage stabilizing equipment
    - Additional capital costs (in the multiple percent range)
    - Efficiency losses (2-30% lost!)
Actual power quality (voltage profile) for rural feeder in India

Load = 75%  Theft = 15%

3 MW Rural Feeder
≈ 10% losses

Source: Bharadwaj and Tongia (2003)
Why a Focus on Distribution?

- It’s where the consumer (and hence, revenue) is
- High losses today
  - Technical losses, 10+ % in rural areas
  - DSM and efficiency measures possible
  - Use of standards required
    - Use a combination of technology, industrial partnership, and regulations
    - Learn from experiences elsewhere
    - Bulk of India's consumption is for just several classes of devices
      - Pumpsets
      - Refrigerators
      - Synchronous motors
US Refrigerator Efficiency Standards

Similar standards can be established for “smart appliances”
Future of Appliances and Home Energy Automation Networks

- Incremental cost of putting networking and processors into appliances approaching a few dollars
  - India has IT strengths and can develop innovations for this sector
  - Could allow time of use and full control (utility benefit/public good/user convenience)
  - Link to a smart distribution system
    - Micro-monitor and Micro-manage every kWh over the network
      - E.g., refrigerators – don’t operate or defrost during peaks (5% of Indian electricity usage)
    - 5% peak management could lead to a 20% cost reduction
    - Italy is already implementing such a system (ENEL)
Objectives and design goals for a new IT-enabled

- Implement a basic infrastructure to...
  - Micro-measure every unit of power across the network
  - Allow real-time information and operating control
  - Devise mechanisms to control the misuse and theft of power through soft control

- Which would...
  - Reduce losses
  - Improve power quality
  - Allow load management
  - Allow system-level optimization for reduced costs
  - Increase consumer utility, satisfaction, and willingness to pay
Additional Benefits

- A system which will offer
  - Outage detection and isolation
  - Remote customer connect & disconnect
  - Theft and tamper detection
  - Real time flows
    - To allow real time pricing
  - Suitability for prepayment schemes
    - Popular in South Africa and elsewhere, where similar problems had been faced
  - Load profiling and forecasting
  - Possible advanced communications and services
    - Information and Internet access
    - Appliance monitoring and control
Network Schematic

~ 20 km

Transmission (~11 kV)

Data Center

Substation

Coupler

Distribution Transformer (pole or ground)

NetCom Device

Coupler

Secondary Distribution Voltage

Users

Quality Assurance Device (Can be off-site outside user control)

Last Few Hundred Meters

(440 or 220 V)

Distribution (11 kV)
Components of the solution

- One segmentation – locational
  - At consumer
    - Meter/GateWay
      - Meter could be pole-side if required
    - In home network
      - Needed connect to enabled devices (appliances)
      - Eventually, homes would also have Decentralized Generation available (?fuel cells, flywheel storage, etc.)
  - Access (low voltage distribution)
    - From gateway to a concentrator, on user side of distribution transformers – Using PowerLine Carrier (PLC)
Solution Components (Cont.)

- Concentrator upwards
  - Concentrator – Each Distribution Transformer (aka Low Voltage Transformer) feeds on the order of 100-200 homes in India (as in Europe). In contrast, US Distribution Transformers feed 5-10 users.
  - Communications medium
    - Over Medium Voltage PLC to the Sub-station
    - or
    - Wireless

- Substation upwards (uplinking)
  - Usually based on leased lines or optical fiber
Technologies for various segments

- **In-Home Network**
  - **Appliances**
    - Emerging Standards are talked about (Maytag, Samsung, GE, etc.)
    - Using Simple Control Protocol (or other appropriate “thin” protocols)

- **Meters**
  - Solid-State meters exist, but not yet the norm in developing countries
  - Most have communications capabilities for external ports
  - Lowest cost solution (if feasible) – PLC – target 5$ incremental cost
Technologies for various segments (cont.)

- **Access**
  - Low Voltage PLC is available today
  - Being explored for Internet access, in fact (Megabits per second)

- **MV**
  - Crossing through transformers remains a technical challenge
  - Going long distances an issue

- **Uplinking**
  - Availability of optical fiber or leased lines can be met through planning
## Technologies vs. Capabilities

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<tr>
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<th>Accuracy</th>
<th>Theft Detection</th>
<th>Communications</th>
<th>Control</th>
<th>Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromechanical Meter</td>
<td>low (has threshold issues for low usage)</td>
<td>poor</td>
<td>expensive add-on</td>
<td>nil</td>
<td></td>
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<tr>
<td>Digital (solid state)</td>
<td>high</td>
<td>Node only</td>
<td>external</td>
<td>Limited</td>
<td>Historical usage reads only</td>
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<tr>
<td>Next Gen. Meter (proposed)</td>
<td>Arbitrarily high</td>
<td>High (network level)</td>
<td>Built-in (on-chip)</td>
<td>Full (connect/disconnect); Extending signaling to appliances</td>
<td>Real-Time control; DSM</td>
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Design Model and Business Case

- Only target specific users
  - All agricultural (almost one-third of the load)
  - All Industrial and larger commercial users
  - Only the larger-size domestic users
    - Estimated 2/3 of homes only use <50 kWh per month

- Include every network node that needs monitoring and/or control
  - Substations
  - Transformers
  - Capacitor banks
  - Relays
  - etc.
Design Model and Business Case (cont.)

- Investment in long run only a few thousand rupees per targeted user (Target <75$ capex)
  - When amortized, implies requirement of improvements in system of only a few percent!
  - Savings will come from
    - Lower losses/theft
    - Increased sales possible
    - Lower operational costs
    - Load management
    - Better consumer experience (and hence, possibility for higher tariffs)
    - Future interaction with smart appliance and smart home networks
Economics of case system

- Estimated System
  - (Rural-centric)
  - 62 Consumers (all classes) per Distr. Transformer
  - 98 Distribution Transformers per Sub-Station

<table>
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<tr>
<th>Number of Nodes</th>
<th>Equipment cost ($)</th>
<th>Cost ($)</th>
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<td>Domestic (applicable)</td>
<td>200,000</td>
<td>15,000,000</td>
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<tr>
<td>Commercial</td>
<td>383,000</td>
<td>28,725,000</td>
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<tr>
<td>Agricultural</td>
<td>673,000</td>
<td>50,475,000</td>
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<tr>
<td>High-Tension</td>
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<tr>
<td>Distribution Transformers</td>
<td>70,306</td>
<td>35,153,000</td>
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<td>Substations</td>
<td>714</td>
<td>3,570,000</td>
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<td>Other IT and infrastructure (capitalized)</td>
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<td>10,000,000</td>
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<td></td>
<td>142,923,000</td>
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<tr>
<td>15% &lt;-annualized rate incl. Amortization</td>
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<tr>
<td>Needed Savings</td>
<td>$ 21,438,450</td>
<td>annually</td>
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<td>11,625,000,000 kWh sold annually</td>
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<td>0.06 Electricity Rate ($/kWh)</td>
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<td>$ 697,500,000 Annual Costs</td>
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<td>3.1% &lt;- Need improvements worth</td>
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Economics (cont.)

- 6-7 year payback on investment (conservative) possible with just 3% improvement in system
- Savings will come from
  - Theft Reduction
  - Time-of-Day and DSM measures (peak reduction)
  - System Quality, reliability, and uptime
  - Higher Collection
Challenges

- **Protocols**
  - Use of thin protocols to reduce capex for embedded systems
  - Security – PLC can be a shared medium

- **PLC**
  - How to couple around transformers or other obstacles
  - How to go long runs with low errors (and high enough bandwidth)
    - Shannon’s theorem provides a limit
  - Noisy line conditions in many developing countries

- **Appliances**
  - Need for standards to bring down costs and ensure inter-operability

- **Design** – Should the PLC signals pass through the meter/gateway directly to appliances?
  - How active or passive should consumer behavior modification be?

- **Costs** (as always)
Development strategies

- Standards
- Pilots
- Technology Transfer
- Indigenous R&D
  - Industrial
  - National Labs
  - Academic
- Partnership between these
A New World for Power Systems

- Includes “smarts” for significant improvements in efficiency
- New services can be enabled once the appropriate infrastructure is in place
- Segmentation of development allows independent, modular innovation, e.g., home automation and appliances
- Developing countries (esp. Asia) can lead the way through leap-frogging
Thank You
Unbundling – Where It Can Lead to?

Current Charges
Customer Charge
Generation 432 kWh @ 5.5082¢ 6.38
Transmission 432 kWh @ 0.2483¢ 1.07
Distribution 432 kWh @ 3.0212¢ 13.05
Transition 432 kWh @ 0.0000¢ 0.00
Pennsylvania Tax Adjustment 0.83
Total DLC Basic Service 45.13

My Pittsburgh, Pennsylvania Bill, January 2003

\[
\frac{45.13}{432 \text{ kWh}} = 10.45 \text{ cents/kWh}
\]

But, excluding the Customer Charge, comes to 8.95 c/kWh

Adding the Customer Charge solely into Distribution increases this by almost 1.5 cents/kWh.

This is a rather high bill versus the US average: \(\approx 6.7 \text{ c/kWh (1999)}\) (excluding end-user taxes)

Regional differences – Northeast
Sectoral – Residential pays more than average