Chapter 2
Background of the Agricultural Power Supply Situation in India and Andhra Pradesh

Abstract In this chapter, we discuss the power supply situation in India and Andhra Pradesh, beginning with a brief historical outline and then describing the current state and structure of the power sector, including its main challenges. We focus on agricultural power supply, exemplifying its major issues and discussing the existing low-equilibrium trap of power quality.

Keywords Power sector · South asia · Agricultural power supply · Irrigation · Low-equilibrium trap

2.1 History of the Indian Power Sector

Since independence in 1947, the power sector in India has been virtually controlled by the Government of India, which created State Electricity Boards that were responsible for the complete supply chain of power, including generation, transmission, and distribution. The reasons for this centralisation, based on socialist ideology, included no-monopoly instincts (profits were reinvested, fair-labour policy, no mark-up prices), economics of scale, control over price structure and the interconnection of State Electricity Boards to enhance system reliability (Tongia 2007). However, the State Electricity Boards turned out to be unprofitable and inefficient and, thus, required high subsidies from the Government of India and state governments to survive. The major reform process started in 1991 with a new government and an upcoming fiscal crisis. By then, the state deficit had reached 11 % of national GDP and, in order to maintain a growth rate of 8 %, high infrastructural investments were required, especially in the power sector.[1] It had become clear that there was hardly any scope for the Government of India to invest sufficient amounts by itself. Therefore, with help from the World Bank, it started to open the power sector to private and foreign investment. This, however,

[1] A general rule, which the Government of India was aware of, states that for a 1 % increase of economic growth a 1.5 % growth rate in the power sector is needed.

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did not mean the introduction of a competitive market. Rather, private investors faced restrictions but were guaranteed a 16 % rate of return, risk reduction and other benefits provided by the Government of India (Pani et al. 2007). Yet, many of the pursued investors stayed away at that time, and the projects that had been established often failed or led to even higher losses than the State Electricity Boards had before them. In the end, the private investment strategy turned out to be very expensive for the Government of India.

During the mid-1990s, the Government of India introduced further structural reforms (second stage of reform process), allowing the states to independently restructure their power sectors. State Electricity Regulation Commissions (SERCs) with a high degree of autonomy and responsibility (e.g., to set tariffs, resolve disputes, and monitor quality) were established, and the states started to unbundle their State Electricity Boards.[2] Andhra Pradesh, in the early 1990s unbundled with hardly any privatisation and is currently considered to be one of the leading states in terms of power generation and distribution (Sreekumar et al. 2007).

The third stage of the reform process was concerned with coordination and consolidation. The Government of India published the Electricity Act 2003 and established incentives for good performance, including ranking of states, competition among them, and rewards for the most efficient ones (Ministry of Law and Justice 2003; Ranganathan 2004). Another focus was directed towards the public with, for example, media campaigns like “power for all” being introduced. Additionally, the SERCs were asked to introduce full metering and to make sure their subsidies were paid back in time. Efficiency was also a target of the act. The Government of India had already established the Bureau of Energy Efficiency in 2002 and introduced new standards for efficiency. Further, private investors were encouraged to invest in a variety of sectors (Swain 2007).

But there has been strong opposition to such reforms, because power is regarded as a social good and many experts have feared that further privatisation would lead to higher electricity prices and limited access to energy for rural populations. In 2000, around 57 %, or 399 million, of the rural households and 12 % (84 million) of the urban households in India did not have access to electricity. By 2011, these numbers had decreased to 33 % for rural households and 6 % for urban households. In total, however, there were still 306 million Indians without access to electricity (World Energy Outlook 2013).

2.2 Structure of the Power Sector in India

Power is mainly generated by state-owned generation corporations (GENCOs) and few private companies. In Andhra Pradesh, for example, private generation contributes to 18 % of total production (Sreekumar et al. 2007).

[2] In this context, unbundling means that each stage of generation, transmission and distribution is carried out by a separate, independent company.

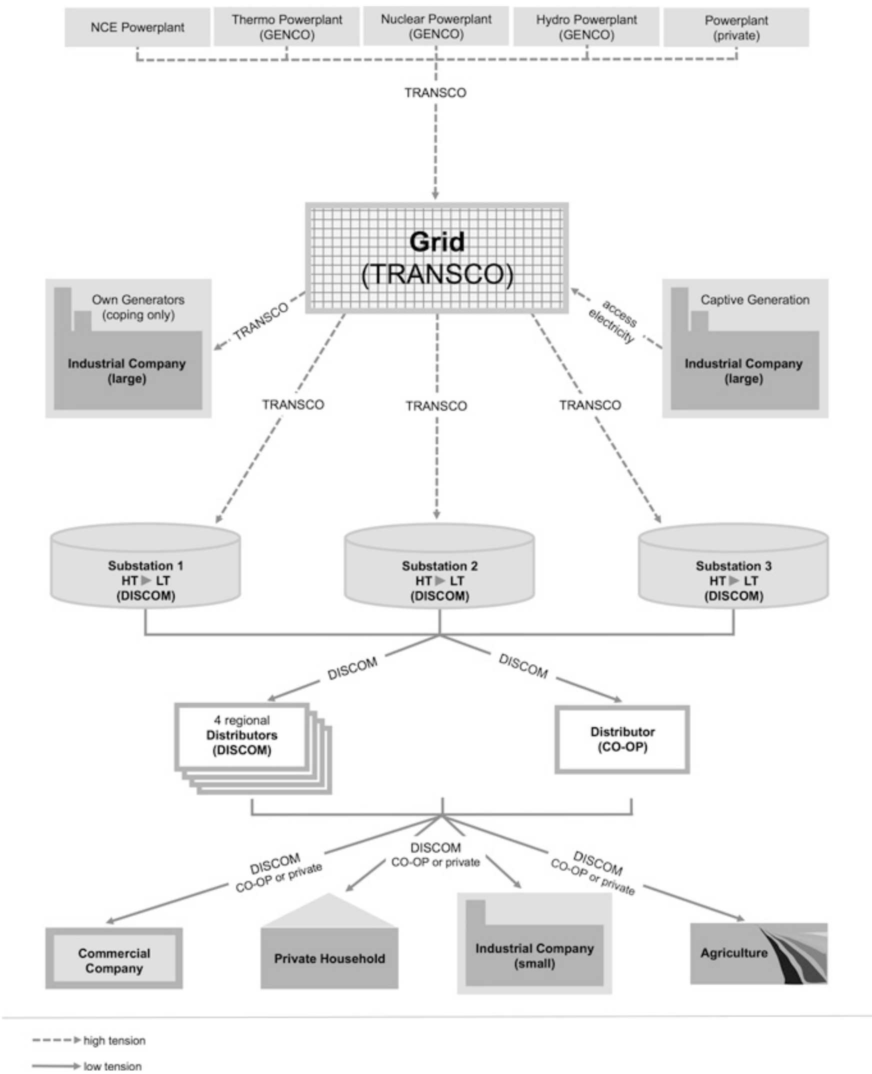

Fig. 2.1 The structure of the power sector in India

Transmission is provided by state-owned transmission corporations (TRANSCOs) on a high-tension basis to substations or directly to large electricity consumers such as the cement industry (Fig. 2.1).

At the substations, distribution companies, which are also state-owned in many states, take over, reduce the tension and distribute the electrical energy to distribution transformers (DTR), which finally forward it to consumers. In some states, private companies are allowed to conduct the final distribution. In Andhra Pradesh, this is not yet possible, but in some areas of Andhra Pradesh co-operative societies

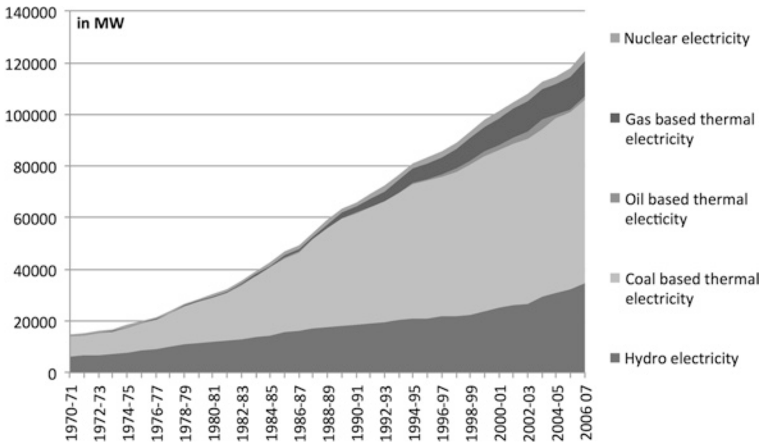

Fig. 2.2 Installed generation capacity excluding renewables in India by source, 1970–2007. *Source* Adapted from CMIE (2008)

that are responsible for final distribution and maintenance have been established (DRUM-Distribution Reform and Management 2006).

The major energy source that has been used up to now is coal (Fig. 2.2), which is abundant in India.[3]

Recently, a focus has been put on gas, as additional sources have been into view, and many private investors used gas, as generation facilities using it can be established very quickly. Renewable energy is being pushed by the Government of India (see Box 1) but still plays a minor role.

A large share of consumption comes from agricultural and industrial customers (Fig. 2.3). Noteworthy is that, despite investments into infrastructure, transmission and distribution losses account for up to 40 % of total generation, at least in some states.

The Government of India has paid roughly 250 billion Indian Rupees (INR) per year, that is about 1 % of GDP, for the losses of the now unbundled State Electricity Boards, with the direct subsidies alone adding up to 100 billion INR (Tongia 2007). Tariffs[4] are fixed and discriminate across consumers as a cross subsidy: private households and agricultural users pay less, sometimes nothing, and industrial and commercial users pay more. This is often regarded as a major source of end-use inefficiency. When industrial and commercial units face high tariffs, they tend to switch to captive power, which is more reliable but also more costly than power from the grid, leading to decreased competiveness (Ghosh and

[3]In many cases, domestic coal is of low quality—containing a high percentage of ash—and located in remote areas, which makes transport expensive, meaning that one needs more coal for "one unit of energy". This has led some companies to import coal.

[4]In India, a tariff refers to the price for electricity per kilowatt-hour, whereas in the United States electricity rates is the usual term.

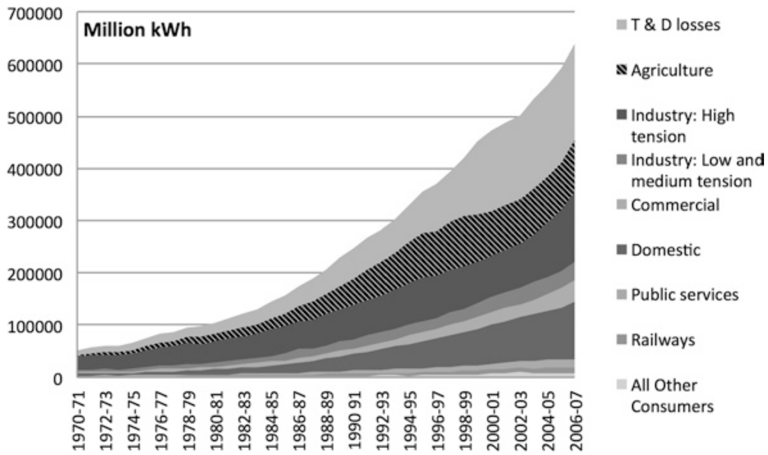

Fig. 2.3 Electric energy use in India by sector, 1970–2007. *Source* Adapted from CMIE (2008)

Kathuria 2014). Meanwhile, farmers, who often get power for free, use highly energy-inefficient assets for irrigation (TARU Leading Edge 2001). The next section discusses in detail the implications of providing free power supply to farmers.

First, however, we need to underline the main problem in the power sector: a continuous power-supply shortage. TRANSCOs and distribution companies are not able to supply at the normal voltage level (440 V for three-phase supply), which results in low-quality supply in the form of unscheduled power cuts, load shedding, fluctuating voltage and erratic frequency. Additionally, the low voltage levels lead to large technical losses and make power theft easier.

The problems of the Indian power sector can be summarised as follows:

- supply shortage, leading to power cuts and low-quality electricity;
- unsustainable and market-distorting cross subsidies;
- large-scale theft and non-payment of bills;
- inefficient and overstaffed utilities, suffering from a high degree of corruption;
- rural villages without access to energy services; and
- an incentive-distorting tariff system that cannot cover costs.

In the following chapters, the discussion will be reduced to the agricultural sector. However, it should become obvious how these problems interrelate with agricultural power supply. Solving agricultural power problems will immediately relieve the other sectors.

Box 1: Efforts to Expand Solar Energy in India

This box is adapted from Sagebiel et al. (2013)

In the Government of India's efforts towards resolving the power-supply problems, the Jawaharlal Nehru National Solar Mission (JNNSM) was initiated in 2010 under India's National Action Plan on Climate Change, aimed at increasing solar photovoltaic (PV) power generation in the country to 22 GW annually by 2022. As part of this process, rural areas are to be equipped with nearly 2 GW of off-grid installations. Under the Remote Village Electrification programme of the Ministry of New and Renewable Energy, 20 million square kilometres of land shall be used for solar PV collectors and 20 million solar lighting systems distributed to rural households. Apart from this, the JNNSM is geared towards facilitating research and development, increasing human capital in the field of PV and expansion of the solar-power manufacturing industry. One main strain on support, however, is financing. The installation of off-grid solar power is directly and indirectly subsidized through the National Bank for Agriculture and Rural Development (Sairam 2012). Off-grid solar systems with a capacity of less than 100 W peak and mini grids with less than 250 W peak receive a 30 % capital subsidy plus a subsidized loan. Harish and Raghavan (2011) criticise this approach, as it is discriminative in favour of smaller systems, whereas the relative costs of solar PV lighting systems decrease with increasing size. Gambhir et al. (2010) note that, although electrification of rural areas without grid connection is mentioned as a priority of the JNNSM, only 7 % of the subsidies were spent on off-grid solutions. Assessments of the first phase of the programme showed that the number of on-grid projects had increased significantly faster than rural off-grid projects. However, by 2012, about 500,000 small lighting systems and 700,000 solar lanterns had been distributed and 1100 MW of on-grid capacity had been installed.

Other governmental programs directly and indirectly facilitated the extension of solar PV power. Unbundling and privatization was one major prerequisite. The Electricity Act 2003 (Ministry of Law and Justice 2003) allowed decentralized power generation. Reforms in 2010 introduced renewable energy certificates and renewable power purchase obligations bind owners of transmission licenses to purchase 5 % of total power from renewable sources. Further, feed-in tariffs, which were introduced in most Indian states make investing in solar PV power attractive for the private sector.

2.3 The Vicious Circle of Agricultural Power Supply

As explained above, the reasons for the low quality of agricultural power supply can be found in the political economy of the Indian agricultural sector. Agriculture plays a crucial role in India's domestic economy, as about 70 % of the population generate their income from agricultural activities (Kimmich 2013a). The sector also fosters food security, and many industries, such as cotton, depend on inputs from it. As a consequence, Indian politics has put a great emphasis on agricultural development. Since the beginning of increased use of electricity for water pumping in the 1960s, the power sector has played a key role in agricultural policies. Farmers have demanded free power supply and, in many cases, received it, subsidised by the state governments. The rationale here has been that power supply is a fundamental requirement for modern irrigation, which is the main driver for increasing agricultural outputs. Kimmich (2010) identified three factors that have enabled the subsidising of agricultural power provision in Andhra Pradesh. First, the increased availability of tube-well technology for groundwater-based irrigation; second, the existing power infrastructure, the regulation of which has allowed political influence to be exerted by the incumbent party; and third, a form of interparty competition that has led to a political contest for votes, with subsidies being a key campaigning issue.

The agricultural power subsidisation policy has enabled more secure food provision and also prevented food-price inflation. Yet, it has not only been economically inefficient overall but also triggered financial difficulties that led to a major change in the governance of power infrastructure in the 1990s. Possibilities for increasing groundwater availability and energy-efficient allocation for its pumping are inseparably linked within the power-irrigation nexus, and analysis of the political economy of the situation suggests that policy change can be most likely induced at the level of power distribution (Kimmich 2013a).

Taking these general conditions as given, the story of the vicious circle of low power quality can be explained more specifically as follows: flat rate power supply to agriculture has led to the use of inefficient pumpsets and excessive water pumping. In the majority of cases, capacitors or motor protection equipment are not being used, which further increases voltage fluctuations, resulting in a low power factor. Voltage fluctuations exist even at the substation level, and three-phase voltage is heavily imbalanced. The overuse of groundwater and power usually forces regulators to reduce power supply to off-peak hours. Often, power is supplied in two phases per day: one in the morning hours and one at night. The night phase has led farmers to use automatic starters. When current is switched on, most pumpsets thus start automatically and simultaneously, resulting in a heavy initial load that burdens the overall infrastructure.

Altogether, these dynamics have led to frequent motor and DTR burnouts and, in consequence, to increasing costs for farmers and utilities. In response, farmers have tended to use even less efficient, yet fluctuation-resistant, pumpsets, as financial incentives to implement DSM for improving energy efficiency are absent. Inefficient pumpsets reduce overall power quality, increasing pumpset and DTR damages, following which farmers and utilities face high repair costs (Tongia 2007). In fact, farmers often pay for DTR repairs themselves, even though they are owned by the utilities (Fig. 2.4).

Adoption of some DSMs—such as provision of standard-approved, ISI-marked, pumpsets with energy-efficient motors or capacitors—could reduce

Fig. 2.4 Farmers collectively repairing their DTR. *Source* Christian Kimmich

Table 2.1 Summary statistics for selected survey variables

Variable	Mean	Standard deviation	Median	Min	Max
Branded pumpset (1 = yes)	0.67			0	1
ISI-marked pumpset (1 = yes)	0.37			0	1
BEE-rated pumpset (1 = yes)	0.06			0	1
Capacitor successfully installed (1 = yes)	0.10			0	1
Motor burnouts per year	1.86	1.64	2	0	12
Costs for motor repair (INR)	2693	1513	2500	200	8500
Age of the pumpset (years)	7.21	5.94	5	0	30
DTR burnouts per year	1.02	1.04	0.70	0	7
Costs for DTR repair (INR)	621	870	400	0	8000

Source Adapted from Kimmich (2013b)

equipment damage and energy consumption. If implemented, such measures could help farmers and utilities to save on repairs and, due to increased energy efficiency, fiscal expenditures on subsidies could be reduced, contributing to the viability of agriculture and benefitting utilities as well as the overall economy through reduced fiscal burdens. Kimmich (2013b) has provided an overview of the share of adopted DSMs by farmers in four districts in Andhra Pradesh, including ISI-marked and BEE-rated pumpsets and capacitors (Table 2.1). Box 2 explains in detail why, although advantageous for all stakeholders, such DSMs have hardly been implemented in India thus far.

The political discussion on subsidised power for farmers is still ongoing and highly controversial. As Shah pointed out, "[t]he only link between the state and the millions of pump irrigators is electricity supply, over which the state has control" (Shah 2009, p. 142). It has also been suggested that institutional changes in regulation (Dubash and Rao 2008), together with physical innovations (Shah 2009) and pilot projects (Mohan and Sreekumar 2010), may enable efficient and equitable outcomes. The next chapter summarises some of the attempts that have been made and discusses different strategies regarding how to escape the vicious circle.

Box 2: The Core Action Situation: A Coordination Problem

This box is adapted from Kimmich (2013b, c)

Substations, covering several villages and distribution transformers (DTR), transform power to the 11 kV level. Depending on a DTR's capacity, between five and 25 pumpsets can be connected, each of which can negatively affect power quality. Exclusion of low-standard pumpsets is, however, difficult. Power quality, or lack thereof, spreads within the electric power distribution grid, affecting all users, as the decision of one farmer to use a low-quality pumpset affects all other pumpsets connected to the same DTR. Meanwhile, if all farmers choose to install low-quality pumpsets, the utilization of a standard-approved pumpset by only one farmer cannot improve power quality. Yet, if all farmers were to install a standard-approved pumpset, repair costs would be drastically reduced and all farmers better off. The use of a capacitor to balance out voltage fluctuations is subject to a similar coordination problem. Furthermore, if only one farmer uses a capacitor, equipment damages may often even *increase*, as "the equipment installed to increase […] productivity is also often the equipment that suffers the most from common power disruptions. And the equipment is sometimes the source of additional power quality problems" (Dugan 2003, p. 2).

Unlike in a dilemma situation, however, no farmer will have an incentive to deviate from a better equilibrium, once reached, as standard-approved pumpsets and capacitors will tend to reduce equipment damages and improve pumping efficiency. A simplified bi-matrix model of the coordination problem at stake here highlights the two equilibria (i.e., Nash equilibria in pure strategies), marked with an asterisk. The equal payoff for the strategy not to invest ~I, and the loss incurred by the one not coordinating, makes this model type an assurance problem (Fig. 2.5).

Econometric analysis of this coordination problem reveals that, under the given conditions, the rational strategy is not to adopt any Demand Side

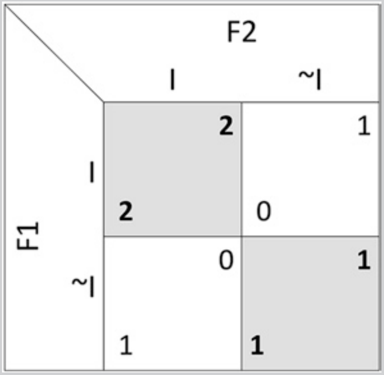

Fig. 2.5 Coordination problem of power quality measures as a 2 × 2 game matrix. Further description: Two farmers (F1; F2) have the choice to invest (I) or not to invest (~I) in measures to improve power quality. Outcomes are ordinal ranks. Investing (I) carries costs, but reduces equipment damage. If both F1 and F2 invest, the payoff is the highest, but if only one farmer invests, he carries the costs without gaining improvements in power quality

Measure solution. This is the low equilibrium of the underlying coordination problem, predicting no adoption at all. Yet, despite their negative impact on the frequency of equipment damage, a small share of the surveyed farmers has adopted Demand Side Measures, partly due to the legal order to make the use of them compulsory and related campaigns and partial enforcement when capacitors were distributed by the government.

Interviews conducted with farmers in Andhra Pradesh in 2010 indicate that only a few of them seem to understand how the Indian electricity system works as a whole. Thus, the interdependence of their decisions, especially in terms of their choosing to use non-standard pumpsets or not and the potentially positive outcomes that could result from simultaneous investment, do not appear to be conceivable for them.

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