# 1
# The Basics

## 1.1 HOW ELECTRICITY WORKS

To understand how electricity can behave as a commodity, we must understand its physical characteristics. We must offer a caution at this point; this is not an engineering text and a full description of alternating current is beyond the scope in hand. The purpose here is to understand electricity sufficiently to understand electricity markets, and to do so we resort to 'folk' definitions, and simplified analogies. Such methods can only go so far without excessive inaccuracy, and hence some aspects of locational market models in particular cannot be covered without a proper engineering description of alternating current (AC). The reader is referred to engineering texts for these. To quote Stoft,[1] 'Most of the basic properties of AC power flows that are needed to design markets can be understood in terms of this essentially DC model, but some important phenomenon are purely AC in nature'.

Electric current involves the movement of an electromagnetic field that is visualised as the collective movement of electrons through an electric conductor, driven by differential concentrations of electrons that repel each other.

Direct current (DC) is driven by voltage differentials between two points on a wire, as we see in Figure 1.1. So if voltage is applied to a line at the point on the left, it will 'push' current to the right. If the current flowing down the line is direct then there will be a consistent voltage differential between the two points.

This movement can then create *heat*, as the electrons give up their energy by repeated collision with the electrons in the atoms in the conductor, or *movement* through the electromagnetic action described below.

The current I is related to the voltage V and the electrical resistance R of the wire by Ohm's law, $V = IR$. The power P (rate of delivery of energy, in this case from a resistor in the form of heat) imparted is the multiple of the voltage applied and the current flowing. So, $P = IV$.

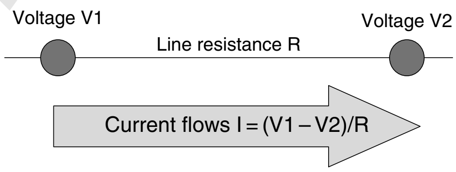


**Figure 1.1** The relationship between current, voltage and resistance by Ohm's law

Equipment such as kettles and conventional electric light bulbs work through the resistance of the conductor creating heat, and they are termed resistive load.

[1] Stoft (2002).

Fleming's rule tells us that electric current can be produced by the movement of a conductor in the presence of a magnetic field, or the movement of a magnetic field across a conductor. The passage of electric current itself creates a magnetic field, and changes in electric current cause changes in the magnetic field. Magnetic fields can be visualised as field lines which are crossed by a conductor. Fleming's rule also works in reverse, so the movement of a magnetic field across a static conductor, or the movement of a conductor across a static field, also causes the conductor to move.

Changes in electric field across the current in the coils of a motor containing a magnet causes the motor to move. The movement of the motor then pushes current in the opposite direction and 'impedes' it. If the power source stopped instantaneously, then the motor would gradually slow as the current created by the motor is converted to heat due to the resistance of the wires. If there is no electrical or mechanical resistance or any inductance anywhere in the circuit, then the motor will turn in perpetual motion as it receives kinetic energy from the current it creates, at the same pace as the kinetic energy creates electrical energy.

A transformer works by the changing currents in the input coil creating a magnetic field in the iron core, which then creates currents in the output coil. Note that it is the change in the current that causes the field. With direct current in the input coil, no current would flow in the output coil. The ratio of numbers of coils determines the current and voltage entering and leaving the transformer.

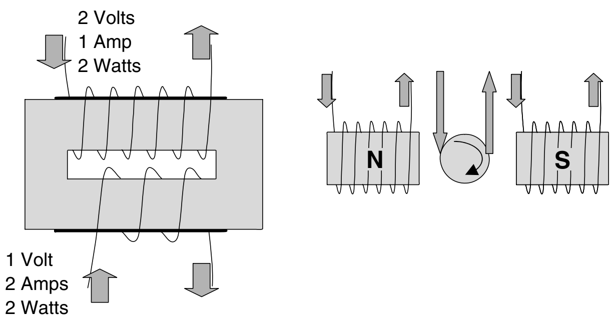


**Figure 1.2** Actions of a transformer and a motor

A voltage that is applied in a cyclic manner by a power generator will cause a cyclic, or alternating, current which has a 'phase' that is measured by the timing of the peaks. Figure 1.3 shows alternating current in three circuits. Circuits A and B are out of phase, and circuits B and C are in phase. If the phase differential is constant,[2] or at least moving very slowly, then the circuits are said to be synchronous.

Electric motors, that use current through coils to drive the motor are said to have an inductive load. A coil, or solenoid has the same impedance effect. The current passing through the coil sets up a magnetic field which then varies as the current varies and then opposes the voltage. Large diameter conductors (such as in high voltage transmission line that are large to reduce resistance) also have an impedance due to the effect of eddy currents behaving like small solenoids. Fluorescent light bulbs also have an inductive load.

[2] For example, positions on the same wire, separated by a long distance.

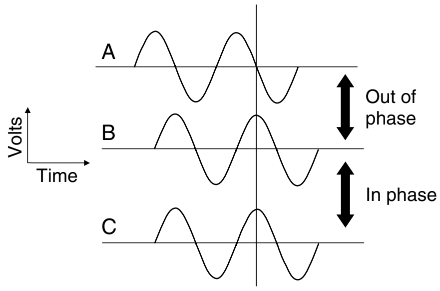


**Figure 1.3** The phase of Alternating Current (AC). C can be connected to B, but A cannot

With direct current, applied by a battery of cells, there will be a consistent voltage differential between the two points. For alternating current (AC) whilst the differential changes, the peak voltage can be the same at both points. Whilst at any instant it is the voltage differential that drives the current, it is more convenient to understand it in terms of the phase differential between the points. To draw power, either for resistive or inductive load, it does not matter which way the current is flowing.

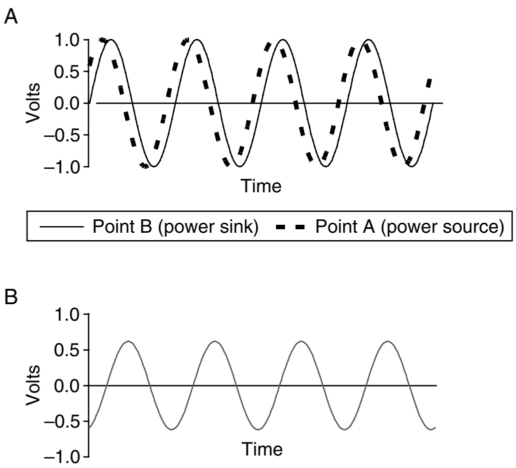


**Figure 1.4** Pictorial representation of how voltage difference between points can result from a phase difference in alternating current between the points without a differential of peak-to-peak voltage

This visualisation of alternating current is in reality a 'DC-like' visualisation that is only correct if the frequency is very low. At high frequencies, the current is not simply related to the voltage differential.

Impedance affects the relative phase, or 'phase angle' between the current and the voltage. The result of this in long transmission line is that the phase angle increases, and to stabilise the power, a reactive source is required. Reactive power is described in the appendix. For a purely inductive load, current lags voltage by 90°, and for a purely capacitive load, current leads voltage by 90°.

## 1.2 EARLY DEVELOPMENT OF THE ELECTRICITY SUPPLY INDUSTRY (ESI)

'As far as domestic applications are concerned, electricity has wrought a revolution that is so complete that it is virtually taken for granted in most homes in the advanced industrial societies' – Buchanan in 'the Power of the Machine'.

Electricity providers are commonly grouped in the category of 'utilities', along with providers of services such as clean water, waste water removal, gas and telecommunication. While electricity provision is commonly regarded as a basic utility that is noticeable in the most developed economies only when it fails, in developing countries electricity provision remains a core aspiration and development indicator.

The electricity industry is a young one, post dating the industrial revolution. Whilst electricity was known by the ancient Greeks in the form of static electricity, it was not until the 'second electrical revolution'[3] of the 1880's that power for lighting and motors was used to any degree, while still over a quarter of the world's population does not have access to electricity.

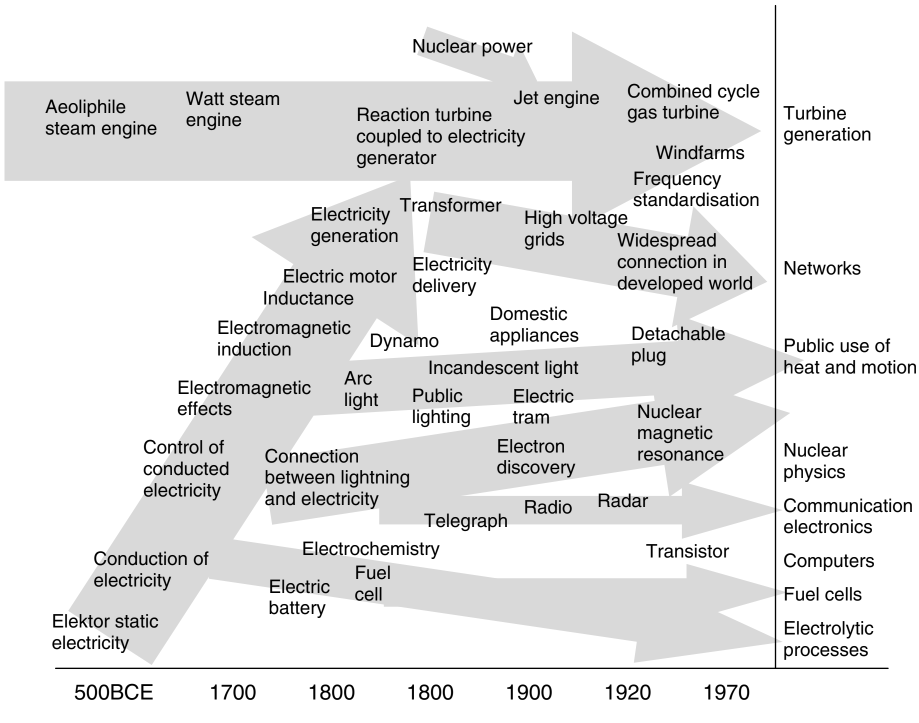


**Figure 1.5** Development of electricity discovery and usage[4]

[3] Term used by Hall (1998). The 'first electrical revolution' was the use of weak current electricity '*schwachstrom*' for telegraph and telephone. Strong electricity for light and power is there termed '*starkstrom*'. The book also contains an excellent account of the impact of the electrical industry on the city of Berlin.

[4] See Kuhn (1962) for a commentary on the discovery of electricity. See Hyman for history in the USA.

The early days of the Electricity Supply Industry (ESI) were driven by discovery and private enterprise. Whilst experimental usage grew during the 19th century, for example the lighting of an opera in Paris in 1844[5] with arc lights, it was the growth of public incandescent lighting using power stations as a source that marks the beginning of the ESI. Development during the first 15 years was rapid as we can see from the chronology[6] below.

1878 Creation of incandescent light bulb by Swan in the UK[7]

1878 Street (arc) lighting in Paris[8]

1879 Creation of long lasting incandescent light bulb by Edison and Jehl in the USA[9]

1881 Opening of Godalming power station in the UK[10]

1882 Opening of Pearl Street power station in the USA[11]

1882 First transmission lines in Germany (2400v DC, 59 km)[12]

1883 Holborn viaduct power station in the UK

1885 Commercially practical transformer (William Stanley)

1885 Hydro power station and 56km transmission in France

1885 Public electricity supply in Norway[13]

1887 Interior lighting in Lloyds Bank, London UK

1887–9 High voltage alternating current transmission in Deptford, UK

1887 Public electricity supply in Japan[14]

1889 Single phase alternating current transmission (4 kV, 21 km) Portland Oregon, USA

1893 Three phase AC transmission (12 kV, 179 km) Germany

1894 generators used to supply motor pumps in mines in Malaysia[15]

1895 Public electricity supply in Australia

In Great Britain, for example, by 1909 there were already laws denying new entry without licence and by 1914 there were 70 power stations in London.

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[5] Munson (1985).
[6] History books differ by the odd year, perhaps due to national pride!
[7] Ensor. Swan and Edison joined to avoid conflict over patents and the company used the Edison patent.
[8] Hall (1998).
[9] Jehl (1937), in which is described how all manner of materials were used as trial filaments, including the beards of the researchers!
[10] Landes (1965).
[11] The moment of the throw of the switch was witnessed by the lighting of 106 light bulbs in the offices of the Morgan bank, winning a bet of $100 for Thomas Edison. The offices of the New York Times were also lit. Source Munson (1985).
[12] Rustebakke *et al.* (1983).
[13] CIGRE (2001).
[14] CIGRE (2001).
[15] CIGRE (2001).

Soon after this burst of development were attempts to standardise. For example, the first attempt to standardise frequency to 60 Hz in the USA was in 1891, although Southern California Edison did not convert from 50 Hz to 60 Hz until 1949.

## 1.3 THE LIFECYCLE OF ELECTRIC POWER

Central to almost all aspects of electricity is the issue of storage. Whilst most commodities can absorb production and demand variations by delivering to stock and withdrawing from stock, this cannot be done for electricity. While we shall see that there are various methods that amount to storage, for the moment we can assume that electricity must be consumed as it is produced.

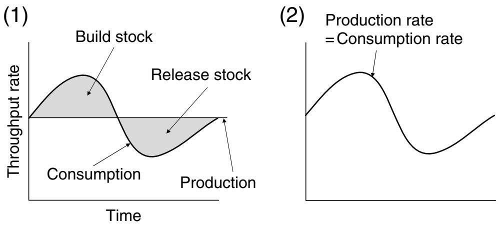


**Figure 1.6** (1) The use of storage to maintain even production through a consumption cycle for storable commodities, (2) The necessity to consume electricity as it is produced, and vice versa

The essential stages in the lifecycle in electric power are:

(i) energy sourcing;
(ii) power generation;
(iii) network transportation, divided into high and low voltage;
(iv) supply management;
(v) consumption.

There are in addition three essential activities that can be considered as part of the supply chain, since every megawatt (MW) of electricity that passes through the network passes through them. They are:

(vi) system operation;
(vii) market operation;
(viii) metering.

And finally, something which cannot be ignored, which is:

(ix) disposal and environmental impact.

**Energy Sourcing** – Starting with the energy source, a natural asset under (initially) common ownership must be exploited to create electricity. This source might be underground (e.g. nuclear or fossil fuel), renewably harvested (e.g. energy crops), or arriving naturally (e.g. wind and water). The sourcing activity may require several activities after initial gathering, such as processing and refining, and then delivery to the power station. The political economics of natural resource extraction have been worked out over the last five thousand years, with the prevailing answer in the late 20th century following the same prevailing political ideology[16] that is driving the ESI. This is the ideology of free markets, as opposed to state run stewardship of national assets. Hence, there is limited opposition to a natural asset being extracted by foreign companies, and then exported, provided that there is sufficient national benefit along the way in the form of royalties, taxes, infrastructure, employment and development. However, the debate over security of supply recognises the fact that national attitudes may change when these resources become scarce in the country of 'ownership'.

**Power generation** – Power generation is the process by which an *in situ* energy supply is converted to electricity and delivered into the electricity transportation infrastructure or directly to a 'host' load. To deliver into the infrastructure requires a high degree of control of the electrical product (for example, synchronisation, ability to vary load to provide and not consume reserve, voltage stability). To generate power, requires not only a source of energy, but fair physical and economic access to the full energy source infrastructure which may include pipeline or rail, road, and ports. Similarly, the generator requires fair physical and economic access to the consuming customer. This requirement may be limited, in the form of adjacent host load, or extensive in terms of geographical distance, and barriers in the forms of regulation, laws and local factors.

**Transportation** – To transmit and distribute power entails extensive and possibly intrusive access requirement to the physical equipment of pylons, transmission and distribution lines, transformers and other equipment and their presence may have a substantial amenity impact in terms of the disruption of views. This requires property rights that would be quite impossible without the support of local and national governments. Transportation is a natural monopoly and hence is subject to regulated prices.

**Supply management** – While consumers require all of the upstream activities, such as generation and transportation, to occur, electricity is delivered to most consumers as a 'bundled' retail product. Consumers pay a price to the suppliers for the delivered product, and the suppliers arrange everything else.

**System operation** – System operation is electrical management of the system, particularly in the short term (less than one day). Because of the need for production and demand to match perfectly and continuously (to a resolution of fractions of a second), then in the short term there is no time for multilateral interactions, and a single system operator must coordinate.

**Market trading** – In the more mature markets, electricity is traded several times from the first producer sale to ultimate consumer delivery.

**Market operation** – Market operation involves the commercial arrangements for energy and capacity trading between participants and the system operator, and coordination of such commercial arrangements between participants.

[16] The mining industry was not changed so much by the imposition of free market political ideology, but by the lessening of rejection to it, in response to an inability to extract using internal funding, expertise, equipment and technology, while treating the resources as national assets to be extracted only by national companies.

**Metering** – While cost is incurred at all points of the supply chain, there is only one source of revenue – the consumer. To pay for electricity, the consumer must have a definitive price and amount to pay for. The meter is clearly the source of information, but in practice the processes are highly complicated. Hence we regard metering as an important and distinct part of the supply chain.

**Disposal and environmental impact** – This can variously be regarded as the last stage of the life cycle of electricity, a by-product of electricity production, or an input factor. Whilst the impact is predominantly incurred in the generation sector, it is rendered inevitable by the act of consumption.

## 1.4 DEVELOPMENT, STRUCTURE, COORDINATION, LEGISLATION OF THE ESI

The organisational development of the ESI responded to the technological capabilities and the sources of funds, and the legislature responded to the organisational development. The variety of structural forms of ownership, operation and control is a result of the technical complexity of the industry and the variety of physical and socio-economic legacy and contexts in which it resides. Electricity in developed countries is regarded as a necessary utility that cannot reasonably be withheld and which must be provided at an affordable price to all consumers. The provision to all customers including the poor, remote, and rural, is called universal service.

In the late 19th century, in which electricity supply could be said to have become an industry, the economic model in the industrial nations for new infrastructure development such as railways and canals was a mixture of private and municipal development, with a series of laws and rulings that first increased the standardisation and coordination and then increased the degree of public ownership and control where national interests dictated that it should do. Then, as much as now, the organisational structure of the ESI was strongly shaped by the prevailing political paradigm.

Closely following attempts to standardise were attempts to regulate. For example, in 1898 Samuel Insull[17] in the USA who tried to impose regulation over 'debilitating competition' and New York and Wisconsin initiated state regulation of utilities in 1907, while England took a more liberal view and allowed a 'rabble of small inefficient electrical undertakings with which parliament had unwisely saddled the country'.[18]

In the early days, electricity usage was largely for municipal installations such as lighthouses[19] and street lighting. In fact, the product sold was light, rather than electricity. The provision of the service used a levy and the municipality contracted directly with the utilities with names such as 'Illinois power and light' which raised debt and equity from private investors. The earliest installations were a matter of civic pride.

With the rapid arrival of new utilities providing light and power and light to an increasing number of buildings, the need for greater coordination became apparent, and legislation[20] was set up to systematise the procedure for setting up public supplies. Then national grids

[17] An Englishman in charge of the Chicago Edison company. Chicago became the 'Electric City'. See Platt (1991).

[18] Ensor (1936).

[19] The discussion of the economics of lighthouses forms part of economic history with legacy that remains relevant to the ESI. See Coase (1974).

[20] For example the 1882 Electricity Act.

began being set up by statute. For example, in the UK, in the 1926 Electricity (Supply) Act. the General Electricity Board was created and the National Grid began development and construction. Between 1920 and 1950, most houses in Europe and America became connected to the networks.

## 1.5 NEW OWNERSHIP STRUCTURE

Whilst nationalisation was the solution in the 1940's to mass provision of standardised public services, the 1980's development was to reduce costs and increase innovation through competition.

The motivations, scope and timescales of the industry players are strongly influenced by their ownership and finance, and there are four key categories of ownership, namely;

(i) investor owned corporations;
(ii) public sector (towns, municipalities, states, nations,[21] public corporations, federal agencies);
(iii) cooperatives (in practice, a very small percentage);
(iv) individuals or privately owned companies (in practice, a very small percentage of large infrastructure and large companies).

Without doubt, the current trend in each sector is towards investor owned corporations, and this destination has been, and is being, arrived at by distinct routes, as shown in Figure 1.7.

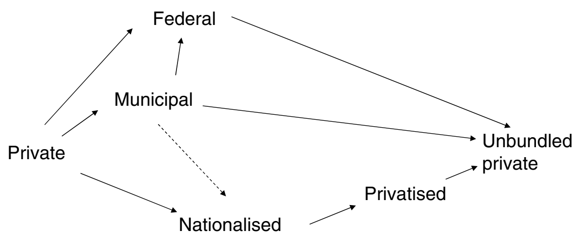


**Figure 1.7** Representation of the different journeys taken in different countries en route to unbundled private companies

Nationalisation (acquisition of private companies by the state) of the ESI was a significant event in each country where it has occurred, and left its legacy on the industry. While the ESI in most countries came under public ownership in some form, there was a significant difference between the national model, in which the ESI concerned electricity alone and the municipal model, in which the municipality has wider responsibilities and was more responsive to local issues than national ones. Intermediate between the two models was the Federal model, which was like nationalisation on a smaller scale.

[21] These may be in the form of public bonds with an actual financial guarantee from government, a de facto guarantee from government, or an actual or implicit government commitment to guarantee revenue. For example the Moyle interconnector from Scotland to Northern Ireland.

The public interest and (notwithstanding privatisation), inherent public ownership of the ESI is apparent in each part of the industry, with the possible exception of the physical process of power generation.

## 1.6 SELECTED COUNTRY EXAMPLES

The development in different countries was different,[22] and strongly influenced by the national political model, whether it be centralised (such as Great Britain or France), federal (such as the USA, Australia and Argentina), or with a strong municipal element (such as in central and northern Europe). A short section cannot do justice to all the countries of the world, and the following is a selection of countries that are of particular importance in the understanding of electricity markets.

### 1.6.1 Europe

**Great Britain** – early development from 1880 was rapid, but the coordination of electricity supply took some time. For example, prior to nationalisation in England and Wales in 1947–8, there were 600[23] separate electricity undertakings based on over 400 generating stations. The Central Electricity Board was initially set up as a statutory corporation like the British Broadcasting Corporation, rather than a nationalised industry, but even just before privatisation, only two fifths of the 569 distribution undertakings were supplied directly by the grid. On nationalisation in 1947, the British Electricity Authority comprised 14 independent area boards, effectively responsible for everything except transmission. Acts of Parliament were passed to facilitate new entrants, but the reality in most cases was that a small new entrant could not surmount the entry barriers or gain fair access to paying customers. For example, the 1983 Energy Act in UK to promote competition to the Central Electricity Generating Board, had, to quote Margaret Thatcher, the Prime Minister at the time, 'no practical effect'.[24] Only the creation of large new players from the national monopoly could achieve change at the desired pace. The industry commenced privatisation in 1990[25] and has since experienced fragmentation in generation, followed by some consolidation, and vertical integration of the unbundled supply businesses with generation businesses. The frontiers of deregulation continued to be rolled back in all areas, including metering, connections, site services and distribution networks.

**France** – The ESI grew from hydropower in the Alps, and was used for electrochemistry and public transport and lighting. The hydro sources were nationalised in the 1920's, the national grid was formed in 1936, and nationalisation in 1946 formed Electricité de France (EDF). EDF, the 'national champion' began the French nuclear programne in the 1970's, culminating in substantial exports of power[26] and a programme of international acquisition.[27] EDF has been an innovator in tariff structures. In France, as in virtually all systems, there is private

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[22] For a summary of several nations as of 1994, See IEA (1994). For current status with respect to degree of competition and degree of public ownership see Rufín (2003).

[23] Weir Committee (1925).

[24] Thatcher (1993).

[25] For a commentary on privatisation and the results, see Henney (1994).

[26] 11% net export as a percentage of domestic production in 2004. Compiled from IEA (June 2005).

[27] For further information on mergers and acquisitions in Europe during the key period of 1998 to 2002 see CERNA (2002).

generation as well as state owned generation. The political model in France is the 'social contract' in which EDF signs a commitment to technical and financial performance. The privatisation of EDF began in November 2005 with a share offering of 15 % of the shares.

**Germany** – The early development in Germany[28] was quite different to that in Great Britain and France. Soon after the birth of the ESI in 1878 in Britain and America, Germany took the lead[29] and led the world until 1913. Indeed Berlin was called the *Elektropolis*[30] by some. Utilities grew from the shareholder owned manufacturers and had detailed contracts with the cities for the supply of light and power, executed by the *Magistrat* of civil government. Partial universal service was mandated, prices were set by regulation, and compulsory purchase by the state was protected against for set periods. Electricity demand in the First World War, and then coal export requirements under reparations agreements from the treaty of Versailles, stimulated the growth of lignite mining for power, and the government entered into what we now call power purchase agreements with the private utilities. Regional utilities with both private and public/private ownerships grew in strength. Nationalisation was envisaged to make a single transmission grid and a pool, and indeed a nationalisation Act was passed in 1919. However, this was never implemented. The extent of public share ownership increased, and the system today is divided into five interconnected control areas, with four dominant vertically integrated utilities. The two largest utilities, RWE and E.ON embarked on a programme of international acquisition.

**Scandinavia** – The well known Nordpool power exchange began in 1991 as Statnett Marked AS in Norway, and was joined successively by Sweden (1996), Finland (1997), Western Denmark (1999) and Eastern Denmark (1999). In Norway, the largely hydro based system is mainly municipal with some state ownership, and most but not all of the grid being state owned. In Denmark, the two major transmission companies are owned by the major generators, Elsam and Elkraft. In Finland, grids are owned by state and private consortium and also market power. There are many distribution companies in each country and consolidation is occurring gradually.

**Greece** remains a state owned vertically integrated monopoly.

**Spain** has a mixture of public and private ownership, with the state being the major shareholder of the national champion ENDESA and the grid RED ELECTRICA. The largest Spanish companies engaged in international acquisition, particularly in South America.

**Italy** – The state owned vertically integrated monopoly Enel was fully privatised in 1999 after nationalisation in 1963 and later transformed to a joint stock company with the state as major shareholder. Transmission was unbundled and smaller generating companies were formed in the 2000's from specified plant and then divested. Independent CCGT power production in the 2000's has been facilitated by market reform, divestment from Enel and production shortfall from the ending of nuclear power, the lack of coal and the high price of oil for oil fired stations.

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[28] Then Prussia. For a fuller account, see Hughes (1983).
[29] Hall (1998); Hughes (1983).
[30] von Weiher, 'Berlins Weg zur Elektropolis' taken from Hughes (1983).

### 1.6.2 Development in the Americas

**USA** – In the USA,[31] whilst there were many investor owned utilities, the Public Utility Commissions had a high degree of control, and could regulate the utilities and set prices. However, the extensive geographical holdings (three utilities controlled over half of the generation in the USA), meant that it was hard to identify value chain costs and therefore hard to regulate them. Accordingly, the Public Utility Holding Company Act (PUHCA)[32] of 1935 forced the breakup of the large utilities into regional vertically integrated utilities. In the same year, the Federal Power Act was passed, which gave the Federal Power Commission (which became the Federal Electricity Regulatory Commission in 1978), the authority to grant licenses for generation and transmission, which gave them the control to ensure fair and non discriminatory access. These two Acts kept power in the hands of the state.

Regional cooperation continued between control areas. In 1927 three utilities signed the PA-NJ agreement to form the first integrated power pool, which became PJM after two more utilities joined in 1956. PJM has developed on a more or less continuous basis since its formation and remains an industry pioneer. There were agreements before that such as the Connecticut Valley Power Exchange which interconnected two utilities, and many utilities still in existence were born, such as the Tennessee Valley Authority (1933) and the Bonneville Power Authority (1935).

Technical management grew through self regulation in the form of Reliability Councils, ten of which merged in the late 1960's to form the North American Electricity Reliability Council NERC.

Policy decisions are often driven by events, and a seminal moment in the history of the ESI in the USA was the 'great Northeast blackout' in the USA in 1965. Like most blackouts in developed economies, this was due to the knock on consequences[33] of a fault, affected 30 million consumers, and spread hundreds of miles from Buffalo to all corners of the Northeast.

In 1973, after the first oil shock, Nixon launched Project Independence with a legal deterrent to generation from imported fossil fuel in the form of oil and natural gas.

In 1978, under the Carter administration, the Public Utilities Regulatory Policy Act (PURPA) was passed, which forced the incumbents to accept power generation from independent 'qualifying facilities' at the avoided cost of incumbent. The qualification condition was generally for power to be generated from renewable sources. In practice, although by 1992, albeit a lean year for construction, 60 % of new entrants were independent power producers, predominantly fossil fired.

The Energy Policy Act 1992 created the capability for the independent generators to sell power directly to the local distribution-and-supply companies, rather than having to sell to power generators. This paved the way for deregulation. The Act also extended the power of the FERC to order utilities to provide transportation on a non discriminatory basis. The implementation of the Act was in FERC Orders 888 and 889 in 1996. FERC 888 in fact

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[31] For further information, see Brennan, Palmer and Martinez (2002). For an account of the development of the ESI in the USA from the early days to the 1980's, see Munson (1985).

[32] In order to support competition, the Senate voted in July 2005 to repeal PUHCA.

[33] This is called a transient stability event. Transient stability is described in 2.3.1.2. One of the reasons that Consolidated Edison took a long term to return is that they did not have 'black start' capability (see section 2.2.21) and needed power from the grid to start.

interpreted transmission in a wide sense and in addition to simply making the wires available to access, specified reserve, balancing and ancillary services.[34]

The standard market design (SMD) was a bold experiment which potentially had far reaching effects beyond open access. It specified:

(i) independent transmission provider;
(ii) flexible transmission service with tradable congestion[35] revenue rights;
(iii) transmission pricing reforms;
(iv) open and transparent energy spot markets; day ahead and real time markets for energy and ancillary services;
(v) congestion management through location marginal pricing;
(vi) market monitoring;
(vii) regional planning process along with a resource adequacy requirement;
(viii) creation of regional state committees to address planning, siting, and other issues.

However, it proved to be a step too far at a time when debate about markets and liberalisation in the post-Enron post-California crisis environment is rife and agreement insufficient. Accordingly the notice of proposed rule making for SMD was terminated in July 2005.[36] The Enron experience and the knock on effect on power marketing firms, both on the way up and the way down, had a significant influence, with the result being that at present, 'At the very least, the pace of wholesale and retail competition and the supporting restructuring and regulatory reforms has slowed considerably since 2000' Joskow (2003).

**Canada** – The Canadian model is quite different to that of the USA, with most utilities being vertically integrated and owned by the provinces, with varying degrees of competition.

**South and Central America** – South America was an early leader in electricity deregulation, with Chile in 1982, followed by Argentina (1992), Peru (1993), Bolivia and Columbia (1993), Central American Countries (1997), and Brazil, Mexico, Ecuador in late 1990's. As of 2002,[37] the degree of private ownership in generation was Chile 90 %, Argentina 60 %, Peru 60 %, El Salvador 40 %, Brazil 30 %, Ecuador 20 %, Costa Rica 10 % and Mexico 10 %.

### 1.6.3 Australasia

**Australia** – Australia is a very large country with six states, two territories and large distances between population centres. Constitutional responsibility for electricity resides with the state governments. State interconnection began in 1959 and continues. The National Electricity Market (NEM) has membership of five states and one territory. Ownership is substantially unbundled and private, with state ownership being highly corporatised.

**New Zealand** – New Zealand is one of the pioneer countries for wholesale markets, beginning in 1996. The generation and transmission sectors were state owned with unbundling of distribution and supply, formation and divestment of small hydro stations and one generator, and deregulation, from 1995 to 1998.

[34] The transmission companies in question generally owned generation assets.
[35] Congestion means exceedance of the limits of the transmission lines.
[36] FERC docket No. RM01-12-000.
[37] Source InterAmerican Development Bank.

### 1.6.4 Asia

**China** – China has the fastest growing ESI in the world. Responsibility for the energy sector is shared between ministries. The semi-autonomous State Power Corporation (SP) was formed in 1997, assuming control after the Ministry of Electric Power. Funding has been a mixture of grants, subsidised loans from central government with some funding from provincial and local utilities. SP plans to unbundle and create full competition in generation in the years to 2010. Organisational of SP is regional.[38]

**India** – India is the world's sixth[39] largest energy consumer. State Electricity Boards run the distribution sector and own most generation. Liberalisation in the 1990's was designed to encourage investment in independent power producers, but third party access through the grid and complex cross subsidies have created commercial challenges, and foreign investment has been limited and with mixed experiences.

**Japan** – The ESI was monopolised by the state during the Second World War, and converted to state owned regional vertically integrated monopolies in 1951. Reform began in 1995 with little change in ownership.

**Russia** – The joint stock company RAO UES, initially a monopoly arising from the Soviet system and still with state ownership of the majority, maintains control of the grid, has divested vertically integrated regional 'Energo's' but retains extensive share ownership of them. Planned reforms are extensive, to encourage foreign investment capital and provide the requisite third party access. Gas is particularly important in Russia due to the large volume produced there.

### 1.6.5 Africa and the Middle East

Ownership remains almost entirely in the hands of states, while independent power production exists to varying degrees. Privatisation is planned in several states, but is commonly delayed or with no particular deadlines.

[38] For a diagram of the 27 companies, see Loi Lei Lai (2001).
[39] Source EIA (2003).