Learn More about the electricity industry and deregulation

Most people have heard about electricity deregulation, but very few understand what it means. In brief, deregulation began as an attempt to restore fairness to electricity markets that have, over the last couple of decades, outgrown the 1930s business model upon which they are based.

Regulation is the legacy of utility business models from years past, which in turn reflected the technology of the times. Prior to 1935, electric companies could and did clutter cities and streets with competing sets of distribution wires and ancillary equipment. Federal legislation passed that year would enable the utility business model as a regionalized monopoly, so that only one utility company's infrastructure served a defined geographic area. In this format, a utility offered the simplicity of one supplier with one price schedule. In return for a monopoly franchise, utility businesses were closely regulated by state-chartered public utility commissions. Commissioners were tasked with representing the consumers' interest by ensuring that the rate for electricity covered the utility's operating costs while providing a fair return to the utility's investors—and no more.

By the 1990s, a number of forces began to challenge the classic electric utility business model. Perhaps the most important forces were (1) the escalating cost of fuels needed to generate power; (2) the growing variety of power generation technologies; (3) and the increased willingness of large quantity consumers to relocate their facilities in search of better electric rates, or to simply generate their own power onsite. The economic tension created by these forces demanded resolution.

Immediately, questions of fairness come to mind. Why should the large consumer be forced to accept the local utility's electric rate when it can buy cheaper power in another location? Why should smaller customers subsidize the cost of serving larger ones? Why should the steady investment returns to utility investors be interrupted? If these returns are interrupted, utilities will find it a lot harder to attract investors. The only cure for that is to raise the rate of return on utility investments. In other words, the cost of capital for utilities would escalate, which in turn raises the cost to produce (and the price to buy) electricity. As electricity prices go up, common citizens begin to petition lawmakers for protection. Average citizens (and lawmakers) do not understand the cost-price relationship for producing electricity; many people assume that electricity prices can be determined by the stroke of a pen, regardless of its actual cost of production. Does it not seem unfair to have elected officials decide the price of electricity? Exactly how are they supposed to do that?

The solution to this dilemma was to open electricity markets to competition. Power generation could be accomplished by competing suppliers. Meanwhile, the local distribution and service portions of electricity provision remain the same—it's still not practical to have competing sets of wires lining the street. By allowing competition among generators, big consumers can get access to lower electricity prices without relocating. But if you open the market to the big consumers, you must open it for all the small businesses and homes, too.

How Does Deregulation Work?

Electricity purchase and consumption is a multi-part task. Keep in mind that electricity consumption is paid for in three parts: (1) the energy commodity itself, in units of kilowatt-hours, or kWh; (2) the capacity for delivering the energy and (3) the ancillary services that ensure the safety and reliability of the distribution system itself. The electricity market constantly adjusts the output of power generators in response to the demands placed on it. A customer's total expenditure for electricity reflects not just the price and volume of these components, but also the time at which they are consumed.

The traditional regulated utility "bundled" together the provision of electricity—a commodity—with the cost of distributing power and servicing the related infrastructure. In contrast, the deregulated market allows customers to shop their commodity needs in the open market. Simply put, you the customer can choose who will supply your electricity. In this market, the local utility retains the responsibility for distribution, service and billing, but acts a as a "middleman" between power generators and the consumer, making wholesale electricity purchases which are in turn delivered to retail consumers.

Regulators recognize that some residential and small business electricity consumers don't wish to be saddled with the many choices presented by deregulation. Therefore, the traditional utility company remains the "provider of last resort," which allows consumers to maintain the simplicity of a traditional utility relationship. However, the utility may not always provide the lowest of prices, especially when its procurement strategy is to make one or two large annual wholesale power purchases in a market that experiences price fluctuations in 15-minute intervals.

The open market for electricity is notoriously volatile for a variety of reasons. The demand for electricity varies with the weather and the time of day. Power generation facilities are not all created equal: some are more expensive to run than others. The cheapest-to-run generators tend to operate the most. The more expensive units add to power supply as demand increases, as it does on hot weekday afternoons when air conditioning is at a premium. Coordinating power generation capacity is an imperfect task, and as a result, demand and supply imbalances create price spikes and volatility.

Whereas the price of an office chair stays constant, 24 hours a day, seven days a week for a long period of time, electricity prices vary by the 15-minute interval. You can store an inventory of chairs in a warehouse until they are sold, but you can't do the same with significant amounts of electricity.

Historical Background of Electricity Legislation

The early electric power industry was developed using direct current transmission, a system in which a relatively low voltage of electricity could travel only over short distances. Typically, numerous power plants were built within a small densely populated area, usually a city, and consumers were able to choose their service provider. This structure created much competition within a local marketplace.

This paradigm began to change as technology rapidly transformed the industry. Newer machines, such as steam turbines, were smaller and less complex, and could create a greater amount of power with a much smaller capital investment. The discovery of alternating current transformers allowed companies to transport power over longer distances at a higher voltage. Savvy entrepreneurs, such as Samuel Insull of Chicago Edison, realized they could exploit the greater economies of scale afforded by these new technologies, and maximize profits by consolidating the smaller utility companies. Fueled by the rapid growth of electricity consumption, the utilities boomed during the early 20th century.

By 1907, Insull had acquired 20 other utility companies and renamed his firm Commonwealth Edison. He and others argued that electric utilities were a “natural monopoly” because it would be inefficient to build multiple transmission and distribution systems due to the great expense of capital investment. Therefore, it was inherent that only one company would dominate the market. The emerging utility monopolies were vertically integrated, meaning they controlled the generation of electric power, its transmission in real time across high-voltage wires, and its low-voltage distribution to homes and businesses. Reformers of the Progressive Era tried to govern these emerging utility monopolies through state regulation. By 1914, 43 states (including California) had established regulatory polices governing electric utilities.

As their businesses grew, the new electric power barons such as Insull began to restructure their companies, largely through the use of holding companies. A holding company is a company that controls a partial or complete interest in another company, and it can be a useful tool in consolidating the operations of several smaller companies. However, the electric utilities of the 1920s began to exploit the use of holding companies to buy up smaller utilities in an effort designed not to improve the company’s operating efficiency, but as a speculative attempt to maximize profits. The growing utility monopolies then exploited this structure, pyramiding holding company on top of holding company, sometimes such that a holding company was as many as ten times removed from the operating company. Each new holding company would buy a controlling interest in the holding company below it and the additional costs and fees for the operating companies were passed along in a higher rate base for the consumer. While the operating companies were subject to state regulation, the holding companies were not; therefore each holding company could issue fresh stocks and bonds without state oversight. The abuse of holding companies allowed for the consolidation of utilities such that by the end of the 1920s, ten utility systems controlled three-fourths of the United States’ electric power business.

The size and complexities of the holding companies were proving state regulation of utilities ineffective and soon caught the attention of the federal government. In 1928, the Federal Trade Commission began a six-year investigation into the market manipulations of the holding companies. The booming utilities of the 1920s traditionally had been seen as relatively secure investments, and utility stocks were held by millions of investors. The pyramidal holding company structure allowed the holding companies to inflate the value of utility securities, which eventually were decimated by the 1929 stock market crash.

Elected to the presidency in 1932, Franklin Delano Roosevelt fought vehemently against the holding companies, calling them “evil” in his 1935 State-of-the-Union address. After a hard-fought campaign by the president and his allies, and in the face of bitter opposition from the utilities, Congress passed the Public Utility Holding Company Act in 1935. PUHCA outlawed the pyramidal structure of interstate utility holding companies, determining that they could be no more than twice removed from their operating subsidiaries. It required holding companies that owned 10% or more of a public utility to register with the Securities and Exchange Commission and provide detailed accounts of their financial transactions and holdings. Holding companies that operated within a single state were exempt from PUHCA. The legislation had a dramatic effect on the operations of holding companies: Between 1938 and 1958 the number of holding companies declined from 216 to 18. This forced divestiture led to a new paradigm for the electricity marketplace which lasted until the deregulation of the 1980s and 1990s: a single vertically-integrated system which served a circumscribed geographic area regulated by either the state or federal government. Roosevelt made the fight for public power an integral part of his New Deal campaign and pushed for other important legislation to that end. In the same year as PUHCA, Congress passed the Federal Power Act of 1935, which gave the Federal Power Commission (FPC) regulatory power over interstate and wholesale transactions and transmission of electric power. The FPC had been established under the Federal Water Power Act of 1920 to encourage the development of hydroelectric power plants. The Commission originally consisted of the secretaries of war, interior and agriculture. The Federal Power Act changed the structure of the FPC so it consisted of five commissioners nominated by the president, with the stipulation that no more than three commissioners could come from the same political party. The Federal Power Act gave the FPC a mandate to ensure electricity rates that are “reasonable, nondiscriminatory and just to the consumer.”

Another component of FDR’s fight for public power was the creation of federal agencies to distribute power to those who were neglected by the traditional utilities, particularly farmers and other customers in rural areas. His administration created the Tennessee Valley Authority (TVA) in 1933 and the Rural Electrification Association (REA) in 1935 to create and finance rural utility companies. The end result of the New Deal era regulatory intervention into the electric industry led to four primary types of service providers: private investor-owned utilities (IOUs) with stock freely traded in the marketplace by shareholders; publicly-owned utilities, such as those owned by municipalities; cooperative utilities which were usually found in rural communities; and federal electric utilities, such as the TVA and REA.

After the tumult of the Roosevelt years and the end of World War II, the electric power industry enjoyed a period of steady growth, driven by both technological and efficiency advances that were reflected in lower prices. Between 1947 and 1973, the growth rate for the industry held steady at about 8% per year and there was little change in the industry structure. The industry began to promote increased electricity usage through advertising campaigns with slogans such as GE's "Live Better Electrically" campaign begun in 1956. As the industry grew and prices continued to decline, there was little need for state and federal regulatory intervention. IOUs were the primary service providers for most Americans and their continued growth and low rates satisfied both consumers and investors.

The energy crisis of the 1970s is often symbolized by images of long lines at gas pumps all over the United States resulting from the 1973 OPEC oil embargo. Oil, coal and natural gas shortages, as well as declining public confidence in the nuclear power industry, contributed to rate increases for consumers throughout all the energy industries, including electricity. Elected in 1976, President Jimmy Carter made energy concerns one of his top priorities. In attacking the demand side of the problem, he waged a public campaign focused on conservation to reduce the American public's high rates of energy consumption. To combat the supply side, he sought to cultivate the growth of new sources of energy, including nuclear power and renewable resources such as solar and wind power. These two approaches were crystallized in the five-part National Energy Act, which Carter signed into law in 1978.

The Public Utility Regulatory Policies Act (PURPA) was the piece of Carter's National Energy Act that affected the electric power industry. It was designed to encourage efficient use of fossil fuels by allowing non-utility generators (known as Qualifying Facilities or QFs) to enter the wholesale power market. PURPA designated two main categories of QFs: co-generators, which use a single fuel source to either sequentially or simultaneously produce electric energy as well as another form of energy, such as heat or steam; and independent power producers, which use renewable resources including solar, wind, biomass, geothermal and hydroelectric power as their primary energy source. Although intended to be an environmental statute, a primary effect of PURPA was to introduce competition into the generation sector of the electricity marketplace, thus challenging the utilities' claim that the electricity market encouraged a "natural monopoly."

One year prior to the National Energy Act, President Carter signed the Department of Energy Organization Act. The act created the Department of Energy by consolidating organizational entities from a dozen department and agencies. Under this legislation, the FPC was replaced by the Federal Energy Regulatory Commission (FERC) as the federal agency that establishes and enforces wholesale electricity rates.

The free-market mania of the 1980s and 1990s further challenged the notion of the electric power industry as a "natural monopoly." Many politicians and economists argued regulation had outlived its value, and the market should determine prices. The telecommunications and transportation industries were deregulated, and the natural gas industry followed suit. Advocates for deregulating the electricity industry argued the implementation of PURPA had proved non-utility generators could produce power as inexpensively and effectively as the regulated utilities. Large industrial consumers searching for lower prices also chimed in and urged federal regulators to pursue deregulation.

In 1992, Congress passed President Bush's Energy Policy Act (EPACT), which opened access to transmission networks to non-utility generators. EPACT further facilitated the development of a competitive market by creating another category of generators known as exempt wholesale generators (EWGs), which were exempted from regulations faced by the traditional utilities. To assist in the implementation of PURPA and EPACT, FERC issued Orders 888 and 889 in April 1996. The two orders provided guidelines on how to open electricity transmission networks on a nondiscriminatory basis in interstate commerce.

Major Features of Electric Service Before and After Legislation

Electricity deregulation is typified by dis-integration, or "unbundling," of the three major elements of vertically-integrated utility service – generation, transmission, and retail service. The following is a comparison of the operation of these elements before and after deregulation.

Generation

Pre-deregulation

IOUs owned or controlled generation needed to meet demand. Power plants owned by IOUs were regulated by the CPUC on a cost-of-service basis. PURPA introduced competition in the form of QFs, which replaced IOU development of power plants. IOUs bought power from QFs under long-term contracts at the IOUs' avoided cost. Approximately 25% of the electricity demand of IOU customers is now met by QFs.

Post-deregulation

The CPUC compelled IOUs to sell fossil power plants to EWGs to facilitate competition and required IOUs to buy and sell all power through the PX at prices set at auction. EWG plants aren't dedicated to serve any particular customers, although EWGs may choose to contract with IOUs (or DWR). Since the enactment of AB 6X in 2001, prices for IOU generation have been set on a cost-of-service basis. The bulk of additional generation needed to meet demand (net short) is supplied via DWR contracts with EWGs.

Transmission

Pre-deregulation

IOUs owned and operated their transmission. IOUs gave priority access for delivery of power to their customers. Excess capacity was available for wholesale wheeling.

Post-deregulation

IOUs still own transmission lines, but operational control is transferred to the ISO. ISO manages the three IOUs' transmission grids as a single, open access system. IOU generation has no more access to the system than competing generators and marketers.

Retail Service

Pre-deregulation

IOUs have an obligation to provide universal service and customers must take bundled service from the IOU at rates set by the CPUC. Self-generation and municipalization are long-term service alternatives.

Post-deregulation

IOUs retain the obligation to provide universal service, but IOU customers may buy electricity from retail competitors at unregulated prices, to be delivered by the IOU, and may freely depart and return to bundled IOU service. IOU customers attempt to recover IOU investments made on behalf of direct access customers through a non-by passable "competition transition charge." In 2001, direct access was suspended to support AB 1X's long-term contracting effort, but not before the direct access load returned to its historic levels and created new stranded costs. IOU customers attempt to recover DWR investments made on behalf of direct access customers through "cost recovery surcharge."

Electricity Prices

Electricity prices, as with other commodity prices, are driven by supply and demand fundamentals.

Electricity Demand

The demand for electricity is mainly driven by the following factors:

- Weather
- Demographics
- Economic Growth

Weather

Electricity demand usually peaks during the warmer months of the year (June-August) and winds down during the cooler months.Any adverse weather conditions will increase the demand for electricity. The warmer the weather is during the summer, the more pronounced the summer peak will be. On the other hand, a cooler summer usually results in a less noticeable summer peak.

Demographics

Changing demographics also affects the demand for electricity, especially for core residential customers. In the US for instance, recent demographic trends indicate an increased population movement to the Southern and Western states. These areas are generally characterized by warmer weather, thus we could expect an increase in demand for cooling in the summer. As electricity currently supplies most of the cooling energy requirements, and natural gas supplies most of the energy used for heating, population movement may increase the demand for electricity for these customers.

Economic Growth

The state of the economy can have a considerable effect on the demand for electricity in the short term. This is particularly true for industrial and to a lesser extent the commercial customers. When the economy is booming, output from the industrial sectors generally increases. On the other hand, when the economy is experiencing a recession, output from industrial sectors drops. These fluctuations in industrial output accompanying the economy affects the amount of electricity needed by these industrial users. For instance, during the economic recession of 2001, natural gas consumption by the industrial sector fell by 6 percent.

Wholesale Electricity Trading

Like any commodity market, the wholesale electricity market establishes a price for its commodityelectricity- by matching supply and demand. The marketplace consists of buyers and sellers whose bids and offers determine a price at which supply is willing to produce electricity and demand is willing to consume it. However, unlike other commodities, electricity must be produced at nearly the same instant it is consumed, requiring a continuous and instantaneous balancing of supply and demand.

In a wholesale electricity marketplace, generators offer prices and quantities of electricity supply they are willing to produce and schedule. At the same time, demand bids the maximum amount it is willing to pay for the anticipated amount to be used. The interaction of these offers and bids ensures that the right amount of power is produced and consumed at an economic price. Establishing this "market price" provides the basis for trading and competition among participants in the market. When supply is tight, prices go up, inducing suppliers to produce more and consumers to use less. When supply is plentiful, prices go down, resulting in less production and normal consumption levels.

There are three levels of trading associated with ISO New England's SMD market: bilateral transactions, short-term forward market trading in the form of a day-ahead market, and a spot market called the real-time market. Market participants can choose to partake in any combination of these. All three trading opportunities are used by participants to manage the daily production and delivery of wholesale electricity throughout New England allowing market participants to manage their portfolios as efficiently as possible.

Bilateral Transactions

The bulk of electricity trading activity is done through bilateral transactions between wholesale buyers and sellers. These are contracts to purchase or sell one or more market products over specified time periods under set prices. In the current New England market, 75 percent of the electricity trading is covered under bilateral contracts, while 25 percent is traded in the real-time market. Under SMD, it is anticipated that roughly the same percentage of demand will be met through bilateral contacts.

Bilateral transactions provide price certainty because these arranged contracts are fixed and not subject to price fluctuations in the day-ahead or real-time markets. What's more, they help market participants balance their portfolios by providing a method for transferring wholesale settlement obligations and reducing certain operating reserve charges.

Short-Term Trading

Electricity supply and demand can be unpredictable and sometimes there are circumstances when production or consumption of electricity changes on short notice. For example, a generator may require urgent maintenance. Weather conditions, such as a heat wave, may influence demand levels, so weather forecasts closer to specific trading days can be used as indicators of electricity needs.

Short-term trading enables participants in the market to manage these short-term changes in predicted generation or demand by adjusting their positions in the market accordingly. Under SMD, this short-term forward market is called the day-ahead market and is available one day ahead of each electricity trading day.

Market participants can also use the day-ahead market to lock in energy prices as a way of managing risk against sudden changes in the real-time, or spot, market.

Spot Market Trading

Spot trading in the form of a real-time market serves to ensure that supply and demand are balanced at all times. Generators and consumers will buy and sell electricity at the spot price for amounts over and under their requirements that are not covered in the day-ahead market or by bilateral transactions.

The spot market carries the most risk for participants as unforeseen events, such as a sudden transmission line failure or unexpected weather, can cause prices to rise or fall dramatically. Nevertheless, the real-time market is essential to fill the gaps in supply where other trades and transactions may not be sufficient to cover the demand.

Market Liquidity and Competition

Liquidity is a measure of the size of a market. A liquid market has many buyers and sellers, allowing hedging of price volatility and reducing the possibility of market manipulation. Under SMD, trading options for market participants increase greatly, which should serve to make the market more liquid, more competitive and more economically efficient. In addition to the three trading opportunities described above, SMD provides complementary tools for managing risk, thus further improving market efficiency. These tools are:

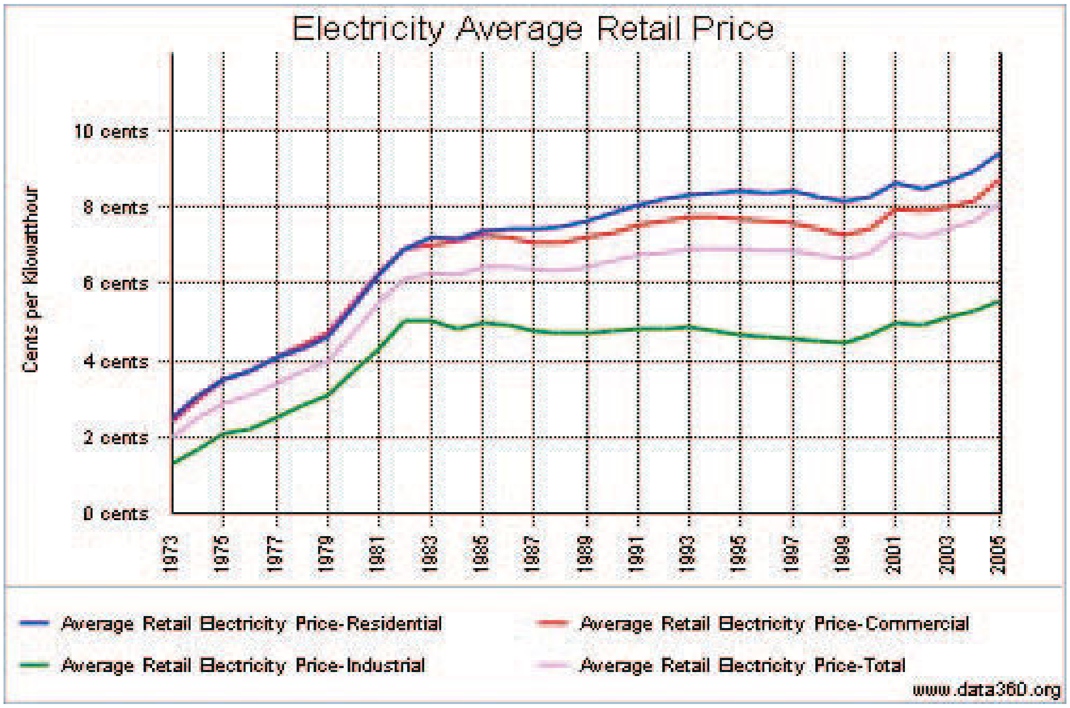
- **Locational Marginal Pricing:** Provides price transparency, or the openness and certainty of pricing data that allows an appropriate estimation of price of electricity across different locations
- **Day-Ahead market that allows virtual trades:** Provides flexibility, or the ability to change how an obligation is met, either through physical or financial positions
- **Financial Transmission Rights:** Provides hedging opportunities to protect against a financial loss If the market is liquid, competitive and efficient, it ensures that the demand for electricity is met at the lowest possible production cost, consistent with security constraints, and it ensures that, at each time and location, the right amount of power is produced and consumed at the correct price.

In the long-term, these prices provide the correct economic signals indicating where investment in the bulk power system is needed, including the location of new generating units, expansion of transmission facilities and participation in demand-side management programs-elements needed in a well-functioning market to alleviate constraints, further increase competition, and continuously improve the system's ability to meet power demand.

How is Electricity Measured?

We measure electricity by how many kilowatt hours (KWh) you use. One KWh will light a 100 watt bulb for 10 hours. The meter multiplier is the factor by which the meter difference is multiplied to determine your usage. Demand or KW is the highest amount of electric usage in any half hour during the bill period. Your total electricity use is the sum of the usage from your meter as shown in the meter detail section of your bill.

Trends In Electricity Prices



Source: Energy Information Administration

The chart shows a 25 year history of the average retail price of electricity in the United States by class from 1973 through 2005.

Conversion Table: Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Electric Power Division.

Unit	Equivalent		
Kilowatt (kW)	1,000	(One Thousand)	Watts
Megawatt (MW)	1,000,000	(One Million)	Watts
Gigawatt (GW)	1,000,000,000	(One Billion)	Watts
Terawatt (TW)	1,000,000,000,000	(One Trillion)	Watts
Gigawatt	1,000,000	(One Million)	Kilowatts
Thousand Gigawatts	1,000,000,000	(One Billion)	Kilowatts
Kilowatthours (kWh)	1,000	(One Thousand)	Watthours
Megawatthours (MWh)	1,000,000	(One Million)	Watthours
Gigawatthours (GWh)	1,000,000,000	(One Billion)	Watthours
Terawatthours (TWh)	1,000,000,000,000	(One Trillion)	Watthours
Gigawatthours	1,000,000	(One Million)	Kilowatthours
Thousand Gigawatthours	1,000,000,000	(One Billion)	Kilowatthours
U.S. Dollar	1,000	(One Thousand)	Mills
U.S. Cent	10	(Ten)	Mills

Evolution of Electricity

Many inventions have taken several centuries to develop into their modern forms and modern inventions are rarely the product of a single inventor's efforts. Each of the inventions listed below were only one small step on the road to the ultimate goal.

Electricity has fascinated human kind since our ancestors first witnessed lightning. In ancient Greece, Thales observed that an electric charge could be generated by rubbing amber, for which the Greek word is electron.

1650 The German physicist Otto von Guericke experimented with generating electricity in 1650.

1729 The English physicist Stephen Gray discovered electrical conductivity in 1729.

1752 Benjamin Franklin proposes the notion of positive and negative charge, conserving a balance except when a deficit is brought about by some means. His famous kite experiments, identifying lightning as a form of electrical discharge, take place in 1752.

1800 Alessandro Volta invents an electric battery, the first source of DC current.

1827 In 1827, using equipment of his own creation, George Simon Ohm determined that the current that flows through a wire is proportional to its cross sectional area and inversely proportional to its length or Ohm's law. These fundamental relationships are of such great importance, that they represent the true beginning of electrical circuit analysis

1831 Michael Faraday experimentally characterizes magnetic induction. The most thorough of early electrical investigators, he formulates the quantitative laws of electolysis, the principles of electric motors and transformers, investigates diamagnetic materials, and posits a physical reality for the indirectly observed magnetic and electrical lines of force.

1876 On April 24, 1877 Charles F. Brush was issued U.S. Patent No. 189,997 for his arc lighting system. There were other arc lamps before Brush's that utilized electromagnets as part of a regulation system but it was the combination of the electromagnet with the ring clutch that made Brush's design superior in regulating the arc.

1879 Thomas Alva Edison invented the light bulb, and houses, shops, factories, schools, streets, and ballparks -- every place you could think of, indoors and out -- could at last be easily illuminated after dark.

1881 Louis Latimer and fellow inventor Joseph V. Nichols received a patent for their invention of the first incandescent light bulb with carbon filament. Prior to this breakthrough, filaments had been made from paper.

1885 During his development of the braking and signaling systems, in the mid 1880s, George Westinghouse became quite interested in electricity. He began pursuing the technology of alternating current and he associated with those who were developing AC devices.

1886 On March 20, 1886, William Stanley demonstrated a system of high voltage transmission via a "parallel connected transformer." The device, combined with high-voltage transmission lines, made it possible to spread electric service over a wide area and allowed alternating current to be available at different voltages.

1888 Heinrich Hertz discovers and measures the waves, radio waves, predicted earlier by Faraday and Maxwell. 1888 Nikola Tesla invents the first practicable AC motor and polyphase power transmission system, Westinghouse acquired exclusive rights to Nikola Tesla's patent for the polyphase system and lured Tesla to join the electric company and continue his work on the AC motor he had developed.

1888 Oliver B. Shallenberger (1860 -1898), a graduate of the U. S. Naval Academy, Shallenberger left the Navy in 1884 to join the Westinghouse company. In 1888 he invented an induction meter for measuring alternating current, a critical element in the Westinghouse AC system.

1901 Elihu Thomson, electrical engineer, inventor, and entrepreneur, was an innovator in electrification in both a technical and corporate sense. Thomson acquired nearly 700 patents in his career, his major contributions included (electrostatic motors, electrical meters, high-pressure steam engines, dynamos, generators and, X-rays).

1902 Although a flashlight is a relatively simple device, its invention did not occur until the late 19th century because it depended upon the earlier invention of the electric battery and electric light bulb. Conrad Hubert received a US patent in 1903, number 737,107 issued August 26, for a flashlight with an on/off switch in the now familiar cylindrical casing containing lamp and batteries