Thomas Alva Edison

His Contributions to Lighting and Power Generation

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This article, as the title suggests, highlights the contributions of Edison in lighting up the world and harnessing electricity to do the job.

The story of Edison's life is a fascinating account of a great inventor and a restless perfectionist with business acumen. He made use of almost every hour of his life of 84 years. " I have lived thousand years in a single night," he often used to say.

Edison's creativity, courage and commitment and an uncanny sense of discerning what would be useful to people were perhaps his main attributes. He was one of the best examples of 'rags to riches' that endeared him to the Americans.

It is virtually impossible to do justice to the inventive genius of a man who had given the world some 3000 inventions, which to a large extent restructured our every day life. *Table* 1 gives a brief list of some of his inventions as presented in the obituary in the *Electrical World* (October 24, 1931).

Figure 1 is a copy of the distinctive handwriting of Edison who considered "the most important line of investigation is the production of electricity direct from carbon". It is not clear what Edison implied by " production of electricity direct from carbon", though it is well known how he produced light from carbon by passing electricity through it. The earlier part of this article briefly recounts this story.

The world had moved ahead from 'Volta's pile' of chemically producing electricity following Michael Faraday's discovery of the principle of magneto machine [1831] which showed how a rotating magnet could produce electricity. Edison not only developed sophisticated storage batteries to produce electricity

Table 1. A Few of Edison's Inventions

Approximate Date	
1868	Electrographic vote recorder.
1869 -1878	Telegraphic repeaters,quadruplex and sextuplex telegraph, printing telegraph, etc.
1875	Electric pen and mimeograph.
1876	Carbon telephone transmitter.
1876	Microtasimeter.
1877	Megaphone.
1877	Phonograph.
1879	Incandescent lamp and light system.
1884	Electric valve ('Edison Effect').
1886	Wireless telegraph to and from moving trains.
1889	Kinetoscope.
1900	Storage battery.

chemically but also developed large rotating machines to produce electricity in bulk to light up many homes, industries and streets.

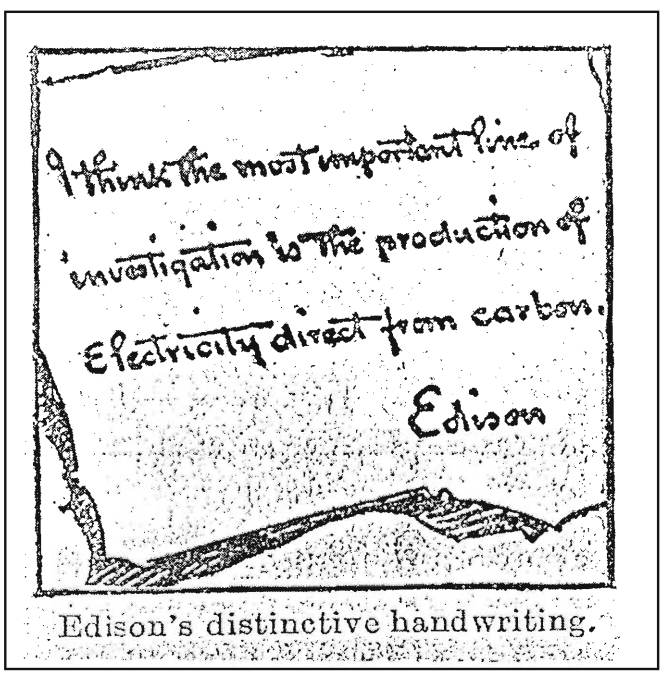

Figure 1. Source: Thomas A Edison: Benefactor of Mankind, F T Miller.

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Electric Light

Electric light was first produced by Humphrey Davy in the form of arc light in 1809–10. Frederick de Molyns, an Englishman, had made the first decisive attempt towards the development of incandescent light in 1841. There were many others in England and America who kept trying until in 1860, Joseph Swan in England devised a lamp with a conductor formed by a strip of carbonized paper. Yet, until the year 1879, arc light developed by William Wallace and Moses G Farmer was the only practicable means of producing light from electricity. But arc light was dazzling, made a hissing sound and burnt itself out quickly. Edison instinctively knew that arc light could not be the answer to the question of how to produce light from electricity, a question that had been intriguing investigators for several decades.

Edison had however to convince himself that electric lighting itself is superior to gas lighting which was prevalent in those days. Edison entered into a thorough investigation of the subject. The data that he gathered in connection with his investigations regarding the production of electric light covered over 40,000 pages written in his own hand. An entry in one of his notebooks reads:

"*Gas will be manufactured less for lighting as the result of electrical competition and more for heating, etc.*"

One hundred and twenty-five years later, we can see how prophetic Edison's conclusion has proven to be.

Once he was convinced that electric light would replace gas light, he thrust himself into perfecting an electric lamp as well as the source of electricity that would light the lamps. "Edison's great effort – not to make a large light, or a blinding light, but a small light having the mildness of gas" began and went surging ahead.

The Filament Lamp

Edison collected funds and set up the Edison Lighting Com-

pany. He launched into his experiments that lasted over 13 months. Edison and team kept working literally day and night, snatching a few hours of sleep in between (Edison's biographers found that Edison worked, on an average, 19½ hours a day till 1902 and 18 hours for many years that followed). Edison kept working with platinum filaments but they kept fusing and at times, making short circuits. He tried with all sorts of materials and the great engineer Nicola Tesla, who had once worked for Edison, called his attempts a 'needle-in-the-hay-stack' method of experimentation. Around April 1879, Edison took the decisive step of placing the filament inside a glass globe, sealing it hermetically and evacuating the globe. Experiments continued but the filaments still continued to fuse.

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Edison modified a pump and succeeded in producing a vacuum of up to one millionth of an atmosphere and was able to secure a light equal to '25 candle power without melting'. Edison was not satisfied and turned his attention to carbon filaments in preference to platinum. Endless experiments followed with carbonized cotton thread until success followed one day. After three days and nights of continuous effort and innumerable failures, Edison and his 'untiring assistant' Batchelor succeeded in making a short piece of carbonized thread from a whole reel that 'did not break while being taken from the mould'. His story of success may be best described in his own words:

"We had to take this piece of carbonized thread to the glass blower's house with the utmost precaution, Batchelor took up the precious carbon, and I marched after him, as if guarding a mighty treasure. To our consternation, just as we reached the glass blower's bench the wretched carbon broke. We turned back to the main laboratory and set to work again. It was late in the afternoon that we produced another carbon, which was again broken by a jeweller's screwdriver falling against it. But we turned back again, and before the night the carbon was completed and inserted in the lamp. The bulb was exhausted of air and sealed and the current turned on, and the sight we had so

Figure 2. Replica of the first light bulb in the reconstructed Menlo Park Laboratory in Dearborn, Michigan, October 1929.

Source: http://www.ieee.org/organizations/society... sources-folder/edison-folder/lighting.htm

long desired to see met our eyes." The historic date was October 21, 1879. The first successful incandescent electric light of the world was invented. Described in Edison's own words: " The day was – let me see – October 21, 1879. We sat and looked, and the lamp continued to burn and the longer it burned, the more fascinated we were. None of us could go to bed. There was no sleep for us for forty hours. We sat and just watched it with anxiety growing into elation. It lasted about forty five hours."

Edison knew that if it burnt for forty five hours, it would burn a hundred hours and longer. And so it did. (*Figure* 2)

In Search of a Fibre for the Filament

Edison now launched himself into finding the right material for the filament and twenty men were despatched at a cost of $100,000 to distant parts of the world, including interior parts of Africa to collect grass and palm and bamboo, almost anything fibrous that could be turned into filaments suitable for mass production of electric lamps. Throughout this worldwide search Edison remained in his laboratory, testing everything that came to him from across the world. Bamboo from Japan proved to be the best source and was used initially to make filaments but finally Edison developed an artificial filament out of a cellulose mixture and electric bulbs were manufactured on a large scale.

A very important discovery by Edison during his years of research for producing electric light was his proposal of parallel circuits for lighting. A single source of arc light produced an almost blinding light but the light from his electric bulb was soft, described as " bright, beautiful, like the mellow sunset of an Italian autumn". It could not, on its own, light up streets and buildings.

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If the bulbs are connected in series they glow dimmer, as would be evident from *Figure* 3. Besides, if one of the bulbs fused, the circuit would break and all lamps would go out.

If, on the other hand, the bulbs were connected in parallel, they

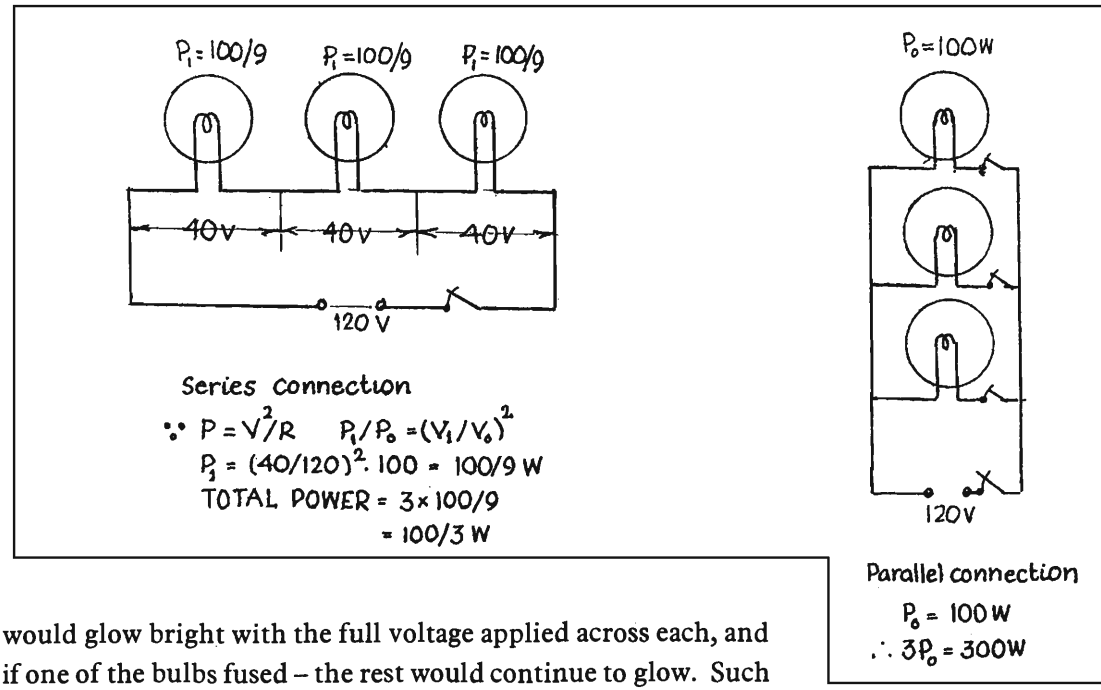


Figure 3. Series and parallel connection of bulbs.

would glow bright with the full voltage applied across each, and if one of the bulbs fused – the rest would continue to glow. Such a proposal would seem to be the most obvious one even to a lay reader of today. The concept of parallel circuits was severely criticized in the days of Edison. Some eminent scientists, including William H Preece, predicted that such a circuit could never be feasible. "The subdivision of the light is an absolute ignis fatuus", (Will-o'-the-wisp) he asserted.

(The literature is unclear about 'subdivision' of light. By 'light', Preece probably meant 'current'). But another scientist, John Tyndall opposed William Preece. Edison however believed in proving his proposals by spectacular demonstrations. He made the Menlo Park power station glow with 30 lamps connected in parallel, each of which could be turned on or off without affecting the others.

The Wizard of Menlo Park

On the New Year's Eve of 1879–80, three thousand visitors arrived by special trains to Menlo Park after dark and were greeted by the 'celestial vision' of the 'great white way' lighted by hundreds of incandescent lamps.

This was unbelievable and even the sceptics were silenced. But a stream of litigations followed. It is true that the filament lamp by Joseph Swan of England made a demonstration ten months previously. But it had remained a laboratory experiment. Edison's incandescent lamp was the first commercial version, which worked and lasted. Edison did win the litigations at the end and what used to be described earlier as 'Ediswan' lamp came to be known as Edison's lamp.

Edison's dream of lighting up streets and buildings and towns at night did not end with the invention of electric lamps. He realized that a reliable and efficient source of electric power and an effective way of transmitting it was imperative and Edison decided to develop and install a complete central-station system. This is what Edison had to say about his plans.

Why 110 Volts?

"As I had to compete with the gas system, it had to be commercially efficient and economical. The network of conductors must be fed from many different points and must be capable of being tapped anywhere. I had to devise a system of metering and the meters must be accurate so that we could charge correctly for the current used. Means had to be devised for maintaining an even voltage on the network; the burning out or breaking of lamps must not affect other lamps and there must be no violent fluctuations of current. One of my largest problems was to build dynamos more efficient and larger than any heretofore made, and I had to make their internal resistance small, so that I could get at least 90 per cent of saleable energy. Of course I had many details to work out, such as switching gear, lamp holders, chandeliers and whatever was necessary to provide so that the system could compete with gas. Why did I fix 110 volts?[1] I based my judgement on the best I thought we could do in the matter of reducing the cost of copper and overcome the difficulty we had in making the lamp filament stable at high voltages."

Voltage used in the US and Canada has since then continued to be 110 volts, Europe and other continents adopted 220-240 volts. In fact for the same power the use of higher voltage means lesser current [$P = VI$] and will require less copper for conducting the current. It is very likely that the filaments that Edison could fabricate were relatively short and thick to be less fragile and hence, they had low resistance. The application of low voltage, therefore, yielded enough power (or candlepower) and he found by trial and error that the use of low voltage was easier to handle and sufficient power could be obtained with 110 volts.

The Central Station and the 'Jumbos'

While Edison was busy developing his filament lamps, he started

working on setting up a central-station system. All possible types of dynamos had been considered. Edison had a number of giant dynamos, driven at 350 revolutions per minute by single cylinder engines of 200 horse power (~ 150 kW) with a combined weight of 30 tons. (*Figure* 4)

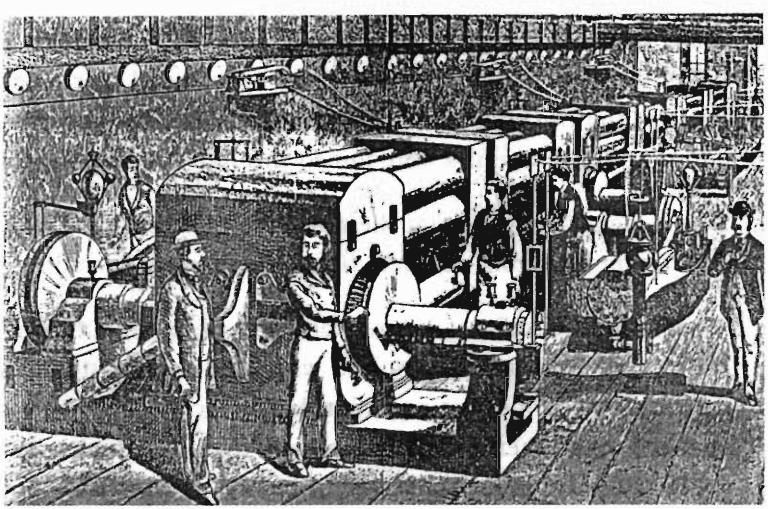
In today's context, such machines are very small (see *Box* 1). The first commercial central station in the US was put in operation at Pearl Street, New York on 4th September, 1882. The Edison Electric Illuminating Company started with a load of 400, 16 candle power (cp) lamps [about 82.5 watts] in 59 buildings wired for 2300 lamps. Six 'jumbo' dynamos were installed, each capable of feeding 1200, 16cp lamp at 110 volts.

Parallel Operation of Generators

Edison took two major steps now. He introduced what is known

Figure 4.

September 15, 1882 – The first district of the Edison Electric Illuminating Company was publicly lighted for the first time on Monday, September 4. Two engines in the Pearl Street station were started and the customers of the company were notified that the light was ready for use. The first attempt to light a large district by incandescent lamps proved entirely successful. Mr Edison's countenance showed that he was greatly pleased. "I have accomplished all that I promised," he said. "It was not without some fear that I started the machinery this evening. I half expected that some new phenomena would interfere with the working of the light. But it has been entirely successful. You will see that we have only one engine running now. It supplies 800 globes with light. We have six engines which will all be in successful operation before the end of the winter. The station contains the largest dynamos in the world, six of a capacity for 5000 lights each. The district has been lighted daily since that time (September 4) and no hitch of any kind has occurred; over 3000 lamps are connected."



Electrical World
October 1, 1932.

Box 1. Dynamos

Michael Faraday's discovery of electromagnetic induction led to the development and production of motors and dynamos. Edison experimented with various types of designs and settled for a new design with horizontal magnetic field and a size (150kW) which was four times the size used in Europe in those days. These were called 'Jumbos' because these generators were so big. DC generators are not used these days but DC motors are still in use. AC generation and transmission replaced DC generation[2]. AC generators rotating at 3000 rpm and rated at 500 MW are fairly typical. The largest generator made so far was rated at 1250MW, more than 8000 times as large as the ones made by Edison. Direct current is now obtained by rectifying alternating current using thyristors.

[2] See D P Sengupta, AC vs DC, *Resonance*, Vol.2, No.10, 1997.

to be parallel operation of generators. Initially, this proved to be difficult but by modifying the governors, he achieved parallel operation which provided a steady supply of electricity at a stable voltage.

The Underground Cables

Edison also introduced the underground cable supply. This proposal was strongly opposed. It was even feared that it might 'blow up the city'. The underground conductors were large size copper rods of half moon section 2.5 ft long. These rods were wound with rope to separate them and forced into a 20ft wrought iron pipe. Asphaltic compound was then forced in and filled the space between the pipe and conductors. Rubber plugs with holes through which the conductors protruded were tightly fitted at the two ends to hold the compound. This constructed a unit and several units were joined through coupling boxes.

The feeders extended from the station not exceeding ½ mile to a 'junction box' from which radiated the interconnected mains.

'Street short circuits were frequent and often shut down the plants and attracted the public with hot paving stones and smoke'. Cable construction and its laying technique have vastly changed since then but it is amazing to think that someone could not only have conceived of but set up a central power station and underground power supply as far back as 1882.

Storage Batteries

While he was engaged in this major venture, Edison made significant improvements in storage batteries and his batteries were the most widely used ones in those days.

Electric Locomotives

Edison used his batteries to develop electric locomotives, which are now-a-days being promoted to avoid environmental pollution.

As has been stated earlier, Edison's inventions were many but his efforts in perfecting incandescent lamps and producing electricity at a commercial level at central stations may perhaps be rated as the one which had the greatest impact on modern civilization.

His Financial Success

It may be stated in passing that the 'lighting and power' was also his greatest financial success. For the first full year of operation of the Pearl Street station–1883 – there was a net loss of $4,457,50

Box 2. Meters

Edison realized that a power system could not succeed as a business if consumers could not be charged for the electrical energy they consumed. So he had to invent (1882) a meter to measure it and charge the consumers accordingly. He used a shunt which would divert a small fraction of the current consumed to precipitate zinc from a zinc-sulphate solution on a plate which would be weighed periodically. The increase in weight would be proportional to the current consumed and the consumer could be charged accordingly.

It was undoubtedly a cumbersome method but was the only method available at that time and it worked. The energy meters used on our households are not electrochemical meters but electromagnetic. A disc rotates due to electromagnetic induction. It rotates faster when larger power is consumed. Since energy consumed is power multiplied by time [1 unit = Kilowatt hour or kWh], the number of rotations provide a measure of the energy consumed. Through a gear mechanism, this is counted and displayed which the meter reader reads, usually once in a month.

These energy meters are now being replaced by more sophisticated electronic meters.

When Edison wrote off this venture, he had lost $4,000,000 earned by his electric light system. His reaction was typical: "Well, it's all gone, but we had a hell of a good time spending it."

while for the year 1884 there was a profit of $33,224. By 1930 the gross revenue came to $2,155,000,000 – representing thousands of plants, all of them descendants of the original Edison Station. Indeed Edison may be considered as one of the main founders of the General Electric Company.

How he took his Failure

One of Edison's projects (of ore-separating for low grade iron deposits) however, turned out to be failure. When Edison wrote off this venture, he had lost $4,000,000 earned by his electric light system. His reaction was typical: "Well, it's all gone, but we had a hell of a good time spending it."

In one important episode his limited theoretical knowledge came in the way. Edison, having chosen direct current launched a press campaign to alert people against the use of alternating current that was proposed for the transmission of bulk power from the Niagara falls over a long distance. Fortunately, Edison lost in his venture to promote direct current. If generation and transmission of direct current was chosen, the growth of power systems would have been significantly retarded. It was Nicola Tesla who helped to steer the power industry in the right direction but it is Edison who should certainly be credited for giving it the first hefty push. Edison committed mistakes but he was right most of the time and he changed the world for the better.

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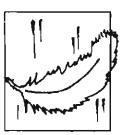
Suggested Reading

[1] **F T Miller, *Thomas A Edison: Benefactor of Mankind,* The PTI Book Depot, Bangalore.**
[2] ***Electrical World*, Issues from 1931–1932.**
[3] **Paul Israel, *Edison: A Life of Invention*, John Wiley & Sons Inc., 1998.**



When Edison, the father of the American Nation, the greatest benefactor of mankind, snatched up the spark of Prometheus in a little pear-shaped glass bulb, it meant that fire had been discovered for the second time, that mankind had been delivered again from the curse of night."

Emil Ludwig, German Historian