Tesla coil

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A **Tesla coil** is an electrical resonant transformer circuit invented by Nikola Tesla around 1891.[1] It is used to produce high-voltage, low-current, high frequency alternating-current electricity.[2][3][4][5][6][7][8] Tesla experimented with a number of different configurations consisting of two, or sometimes three, coupled resonant electric circuits.

Tesla used these coils to conduct innovative experiments in electrical lighting, phosphorescence, X-ray generation, high frequency alternating current phenomena, electrotherapy, and the transmission of electrical energy without wires. Tesla coil circuits were used commercially in sparkgap radio transmitters for wireless telegraphy until the 1920s,[1][9][10][11][12][13] and in medical equipment such as electrotherapy and violet ray devices. Today their main use is for entertainment and educational displays, although small coils are still used today as leak detectors for high vacuum systems.[8]

Tesla coil

Tesla coil at Questacon – the National Science and Technology center in Canberra, Australia

Uses	Application in educational demonstrations, novelty lighting, music
Inventor	Nikola Tesla
Related items	Transformer, electromagnetic field

Contents

Theory

A Tesla coil transformer operates in a significantly different fashion from a conventional (i.e., iron core) transformer. In a conventional transformer, the windings are very tightly coupled and voltage gain is determined by the ratio of the numbers of turns in the windings. This works well at normal voltages, but, at high voltages, the insulation between the two sets of windings is easily broken down and this prevents iron-cored transformers from running at extremely high voltages without damage, unless they are immersed in oil or SF_6.

Unlike those of a conventional transformer (which may couple 97%+ of the fields between windings), a Tesla coil's windings are "loosely" coupled, with a large air gap, and thus the primary and secondary typically share only 10–20% of their respective magnetic fields. Instead of a tight coupling, the coil transfers energy (via loose coupling) from one resonant circuit (the primary) to the other (the secondary) resonant at the same frequency, over a number of radio frequency cycles.

Tesla coil in Nikola Tesla Memorial Center (Smiljan, Croatia)

As the primary energy transfers to the secondary, the secondary's output voltage increases until all of the available primary energy has been transferred to the secondary (less losses). Even with significant spark gap losses, a well-designed Tesla coil can transfer over 85% of the energy initially stored in the primary capacitor to the secondary circuit. The voltage achievable from a Tesla coil can be significantly greater than a conventional transformer, because the secondary is resonant with the primary. Also, the voltage per turn in any coil is higher because the rate of change of magnetic flux is at high frequencies.

With the loose coupling the voltage gain is instead proportional to the square root of the ratio of secondary and primary inductances. Because the secondary winding is wound to be resonant at the same frequency as the primary, this voltage gain is also proportional to the square root of the ratio of the primary capacitor to the stray capacitance of the secondary to ground.

History

The original Tesla coil transformer employed a capacitor which, upon break-down of a short spark gap, became connected to a coil of a few turns (the primary winding set), forming a resonant circuit with the frequency of oscillation, usually 20–100 kHz, determined by the capacitance of the capacitor and the inductance of the coil. The capacitor was charged to the voltage necessary to rupture the air of the gap during the input line cycle, about 10 kV by a line-powered transformer connected across the gap. The line transformer could tolerate the short circuit occurring while the gap remained ionized, or for the few milliseconds until the high frequency current had died away.

The spark gap is set up so that its breakdown occurs near to the peak voltage of the input line voltage to maximize the voltage across the capacitor. The sudden current through the spark gap causes the primary resonant circuit to "ring" at its resonant frequency. This ringing continues until the spark across the gap is quenched when the input line voltage drops towards zero. Hence the duration of the spark is about one quarter of the line input AC cycle.

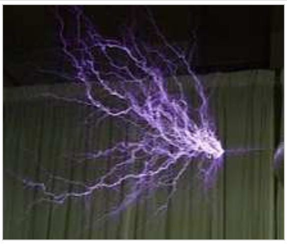
A more prominent secondary winding, with vastly more turns of thinner wire than the primary, was positioned to intercept some of the magnetic field of the primary. The secondary was designed to have the same frequency of resonance as the primary using only the stray capacitance of the winding itself to ground and that of any "top hat" placed at the upper end. The lower end of the long secondary coil must be grounded to the surroundings.

The later and higher-power coil design has a single-layer primary and secondary. These Tesla coils are often used by hobbyists and at venues such as science museums to produce long sparks. The *American Electrician*[14] gives a description of an early Tesla coil wherein a glass battery jar, 15 × 20 cm (6 × 8 in) is wound with 60 to 80 turns of AWG No. 18 B & S magnet wire (0.823 mm^2). Into this is slipped a primary consisting of eight to ten turns of AWG No. 6 B & S wire (13.3 mm^2) and the whole combination is immersed in a vessel containing linseed or mineral oil.[15]

1902 design

Tesla's 1902 design for his advanced magnifying transmitter used a top terminal consisting of a metal frame in the shape of a toroid, covered with hemispherical plates (constituting a very large conducting surface). The top terminal has relatively small capacitance, charged to as high a voltage as practicable.[16] The outer surface of the elevated conductor is where the electrical voltage chiefly occurs. It had a large radius of curvature, or was composed of separate elements which, irrespective of their own radii of curvature, were arranged close to each other so that the outside ideal surface enveloping them has a large radius.[17] This design allowed the terminal to support very high voltages without generating corona or sparks. Tesla, during his patent application process, described a variety of resonator terminals at the top of this later coil.[18]

Modern-day Tesla coils



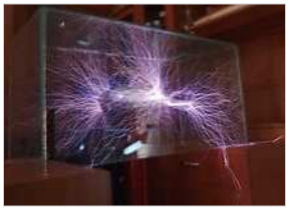
Electric discharge showing the lightning-like plasma filaments from a 'Tesla coil'

Modern high-voltage enthusiasts usually build Tesla coils similar to some of Tesla's "later" air-core designs. These typically consist of a primary tank circuit, a series LC (inductance-capacitance) circuit composed of a high-voltage capacitor, spark gap and primary coil, and the secondary LC circuit, a series-resonant circuit consisting of the secondary coil plus a terminal capacitance or "top load". In Tesla's more advanced design, the secondary LC circuit is composed of an air-core transformer secondary coil placed in series with a helical resonator. Most modern coils use only a single helical coil comprising both the secondary and primary resonator. The helical coil is then connected to the terminal, which forms one 'plate' of a capacitor, the other 'plate' being the earth (or "ground"). The primary LC circuit is tuned so it resonates at the same frequency as the secondary LC circuit. The primary and secondary coils are magnetically coupled, creating a dual-tuned resonant air-core transformer. Earlier oil-insulated Tesla coils needed large and long insulators at their high-voltage terminals to prevent discharge in air. Later Tesla coils spread their electric fields over large distances to prevent high electrical stresses in the first place, thereby allowing operation in free air.

Tesla coil (discharge).

Most modern Tesla coils use simple toroids, typically fabricated from spun metal or flexible aluminum ducting, to control the high electrical field near the top of the secondary and to direct sparks outward and away from the primary and secondary windings. It is better if these top elements are fastened high above the top of the coil to minimise the possibility of flashover to the coils.

More advanced Tesla coil transmitters involve a more tightly coupled air-core resonance transformer network or "master oscillator" the output of which is then fed to another resonator, sometimes called the "extra coil". The principle is that energy accumulates in the extra coil and the role of transformer secondary is played by the separate master oscillator secondary; the roles are not shared by a single secondary. In some modern three-coil magnifying transmitter systems, the extra coil is placed some distance from the transformer. Direct magnetic coupling to the upper secondary is not desirable, since the third coil is designed to be driven by injecting RF current directly into the bottom end.


Tesla coil in terrarium (I)

This particular Tesla coil configuration consists of a secondary coil in close inductive relation with a primary, and one end of which is connected to a ground-plate {the earth}, while its other end is led through a separate self-induction coil (whose connection should always be made at, or near, the geometrical center of that coil's circular aspect, to secure a symmetrical distribution of the current), and of a metallic cylinder carrying the current to the terminal. The primary coil may be excited by any desired source of high-frequency current. The important requirement is that the primary and secondary sides must be tuned to the same resonant frequency to allow efficient transfer of energy between the primary and secondary resonant circuits. The conductor of the shaft to the terminal (topload) is in the form of a cylinder with smooth surface of a radius much larger than that of the spherical metal plates, and widens out at the bottom into a hood (which is slotted to avoid loss by eddy currents). The secondary coil is wound on a drum of insulating material, with its turns close together. When the effect of the small radius of curvature of the wire itself is overcome, the lower secondary coil behaves as a conductor of large radius of curvature, corresponding to that of the drum. The top of the extra coil may be extended up to the terminal and the bottom should be somewhat below the uppermost turn of the primary coil. This lessens the tendency of the charge to break out from the wire connecting both and to pass along the support.

Primary switching

Modern transistor or vacuum tube Tesla coils do not use a primary spark gap. Instead, the transistor(s) or vacuum tube(s) provide the switching or amplifying function necessary to generate RF power for the primary circuit. Solid-state Tesla coils use the lowest primary operating voltage, typically between 155 to 800 volts, and drive the primary winding using either a single, half-bridge, or full-bridge arrangement of bipolar transistors, MOSFETs or IGBTs to switch the primary current. Vacuum tube coils typically operate with plate voltages between 1500 and 6000 volts, while most spark gap coils operate with primary voltages of 6,000 to 25,000 volts. The primary winding of a traditional transistor Tesla coil is wound around only the bottom portion of the secondary (sometimes called the resonator). This helps to illustrate operation of the secondary as a pumped resonator. The primary 'induces' alternating voltage into the bottom-most portion of the secondary, providing regular 'pushes' (similar to providing properly timed pushes to a playground swing). Additional energy is transferred from the primary to the secondary inductance and top-load capacitance during each "push", and secondary output voltage builds (called 'ring-up'). An electronic feedback circuit is usually used to adaptively synchronize the primary oscillator to the growing resonance in the secondary, and this is the only tuning consideration beyond the initial choice of a reasonable top-load.

In a dual resonant solid-state Tesla coil (DRSSTC), the electronic switching of the solid-state Tesla coil is combined with the resonant primary circuit of a spark-gap Tesla coil. The resonant primary circuit is formed by connecting a capacitor in series with the primary winding of the coil, so that the combination forms a series tank circuit with a resonant frequency near that of the secondary circuit. Because of the additional resonant circuit, one manual and one adaptive tuning adjustment are necessary. Also, an interrupter is usually used to reduce the duty cycle of the switching bridge, to improve peak power capabilities; similarly, IGBTs are more popular in this application than bipolar transistors or MOSFETs, due to their superior power handling characteristics. Performance of a DRSSTC can be comparable to a medium-power spark-gap Tesla coil, and efficiency (as measured by spark length versus input power) can be significantly greater than a spark-gap Tesla coil operating at the same input power.


Demonstration of the Nevada Lightning Laboratory (http://www.lightninglab.org/concept/index.html) 1:12 scale prototype twin Tesla Coil at Maker Faire 2008

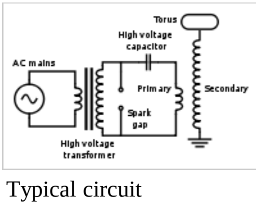
Practical aspects of design

High voltage production

A large Tesla coil of more modern design often operates at very high peak power levels, up to many megawatts (millions of watts[19]). It is therefore adjusted and operated carefully, not only for efficiency and economy, but also for safety. If, due to improper tuning, the maximum voltage point occurs below the terminal, along the secondary coil, a discharge (spark) may break out and damage or destroy the coil wire, supports, or nearby objects.

Tesla experimented with these, and many other, circuit configurations (see right). The Tesla coil primary winding, spark gap and tank capacitor are connected in series. In each circuit, the AC supply transformer charges the tank capacitor until its voltage is sufficient to break down the spark gap. The gap suddenly fires, allowing the charged tank capacitor to discharge into the primary winding. Once the gap fires, the electrical behavior of either circuit is identical. Experiments have shown that neither circuit offers any marked performance advantage over the other.

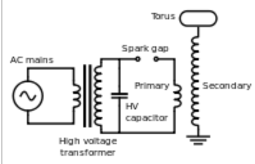
Tesla coil schematics



Typical circuit configuration
Here, the spark gap shorts the high frequency across the first transformer that is supplied by alternating current. An inductance,

However, in the typical circuit, the spark gap's short circuiting action prevents high-frequency oscillations from 'backing up' into the supply transformer. In the alternate circuit, high amplitude high frequency oscillations that appear across the capacitor also are applied to the supply transformer's winding. This can induce corona discharges between turns that weaken and eventually destroy the transformer's insulation. Experienced Tesla coil builders almost exclusively use the top circuit, often augmenting it with low pass filters (resistor and capacitor (RC) networks) between the supply transformer and spark gap to help protect the supply transformer. This is especially important when using transformers with fragile high-voltage windings, such as neon sign transformers (NSTs). Regardless of which configuration is used, the HV transformer must be of a type that self-limits its secondary current by means of internal leakage inductance. A normal (low leakage inductance) high-voltage transformer must use an external limiter (sometimes called a ballast) to limit current. NSTs are designed to have high leakage inductance to limit their short circuit current to a safe level.

not shown, protects the transformer. This design is favoured when a relatively fragile neon sign transformer is used.



Alternative circuit configuration
With the capacitor in parallel to the first transformer and the spark gap in series to the Tesla-coil primary, the AC supply transformer must be capable of withstanding high voltages at high frequencies.

Tuning precautions

The primary coil's resonant frequency is tuned to that of the secondary, using low-power oscillations, then increasing the power until the apparatus has been brought under control. While tuning, a small projection (called a "breakout bump") is often added to the top terminal in order to stimulate corona and spark discharges (sometimes called streamers) into the surrounding air. Tuning can then be adjusted so as to achieve the longest streamers at a given power level, corresponding to a frequency match between the primary and secondary coil. Capacitive 'loading' by the streamers tends to lower the resonant frequency of a Tesla coil operating under full power. For a variety of technical reasons, toroids provide one of the most effective shapes for the top terminals of Tesla coils.

Air discharges

While generating discharges, electrical energy from the secondary and toroid is transferred to the surrounding air as electrical charge, heat, light, and sound. The process is similar to charging or discharging a capacitor, except that a Tesla coil uses AC instead of DC. The current that arises from shifting charges within a capacitor is called a displacement current. Tesla coil discharges are formed as a result of displacement currents as pulses of electrical charge are rapidly transferred between the high-voltage toroid and nearby regions within the air (called space charge regions). Although the space charge regions around the toroid are invisible, they play a profound role in the appearance and location of Tesla coil discharges.

A small, later-type Tesla coil in operation: The output is giving 43-cm sparks. The diameter of the secondary is 8 cm. The power source is a 10 000 V, 60 Hz current-limited supply.

When the spark gap fires, the charged capacitor discharges into the primary winding, causing the primary circuit to oscillate. The oscillating primary current creates a magnetic field that couples to the secondary winding, transferring energy into the secondary side of the transformer and causing it to oscillate with the toroid capacitance to ground. The energy transfer occurs over a number of cycles, and most of the energy that was originally in the primary side is transferred into the secondary side. The greater the magnetic coupling between windings, the shorter the time required to complete the energy transfer. As energy builds within the oscillating secondary circuit, the amplitude of the toroid's RF voltage rapidly increases, and the air surrounding the toroid begins to undergo dielectric breakdown, forming a corona discharge.

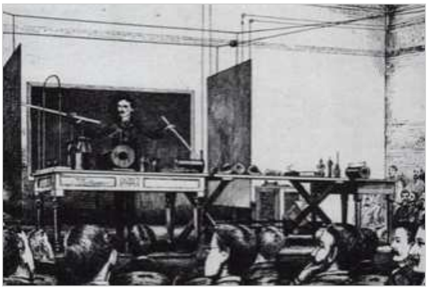
As the secondary coil's energy (and output voltage) continue to increase, larger pulses of displacement current further ionize and heat the air at the point of initial breakdown. This forms a very conductive "root" of hotter plasma, called a leader, that projects outward from the toroid. The plasma within the leader is considerably hotter than a corona discharge, and is considerably more conductive. In fact, its properties are similar to an electric arc. The leader tapers and branches into thousands of thinner, cooler, hair-like discharges (called streamers). The streamers look like a bluish 'haze' at the ends of the more luminous leaders, and transfer charge between the leaders and toroid to nearby space charge regions. The displacement currents from countless streamers all feed into the leader, helping to keep it hot and electrically conductive.

The primary break rate of sparking Tesla coils is slow compared to the resonant frequency of the resonator-topload assembly. When the switch closes, energy is transferred from the primary LC circuit to the resonator where the voltage rings up over a short period of time up culminating in the electrical discharge. In a spark gap Tesla coil, the primary-to-secondary energy transfer process happens repetitively at typical pulsing rates of 50–500 times per second, depending on the frequency of the input line voltage, and previously formed leader channels do not get a chance to fully cool down between pulses. So, on successive pulses, newer discharges can build upon the hot pathways left by their predecessors. This causes incremental growth of the leader from one pulse to the next, lengthening the entire discharge on each successive pulse. Repetitive pulsing causes the discharges to grow until the average energy available from the Tesla coil during each pulse balances the average energy being lost in the discharges (mostly as heat). At this point, dynamic equilibrium is reached, and the discharges have reached their maximum length for the Tesla coil's output power level. The unique combination of a rising high-voltage radio frequency envelope and repetitive pulsing seem to be ideally suited to creating long, branching discharges that are considerably longer than would be otherwise expected by output voltage considerations alone. High-voltage discharges create filamentary multibranched discharges which are purplish-blue in colour. High-energy discharges create thicker discharges with fewer branches, are pale and luminous, almost white, and are much longer than low-energy discharges, because of increased ionisation. A strong smell of ozone and nitrogen oxides will occur in the area. The important factors for maximum discharge length appear to be voltage, energy, and still air of low to moderate humidity. However, even more than 100 years after the first use of Tesla coils, many aspects of Tesla coil discharges and the energy transfer process are still not completely understood.

Applications

Tesla coil circuits were used commercially in sparkgap radio transmitters for wireless telegraphy until the 1920s,[1][9][10] and in electrotherapy and pseudomedical devices such as violet ray. Today, their main use is entertainment and educational displays. Tesla coils are built by many high-voltage enthusiasts, research institutions, science museums, and independent experimenters. Although electronic circuit controllers have been developed, Tesla's original spark gap design is less expensive and has proven extremely reliable.

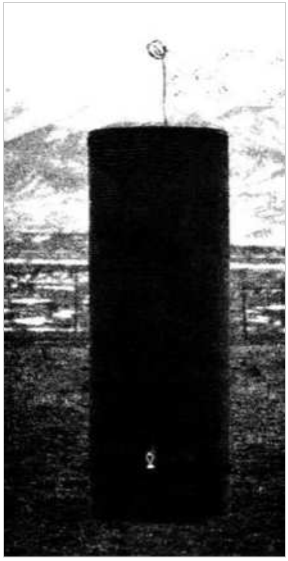
Wireless power transmission



Tesla demonstrating wireless power transmission in a lecture at Columbia College, New York, in 1891. The two metal sheets are connected to a Tesla coil oscillator, which applies a high radio frequency oscillating voltage. The oscillating electric field between the sheets ionizes the low pressure gas in the two long Geissler tubes he is holding, causing them to glow by fluorescence, similar to neon lights.

Tesla used his Tesla coil circuits to perform the first experiments in wireless power transmission at the turn of the 20th century,[20][21][22] In the period 1891 to 1904 he experimented with high AC voltages on elevated capacitive terminals.[21][22][23] In demonstrations before the American Institute of Electrical Engineers[23] and at the 1893 Columbian Exposition in Chicago he lit light bulbs from across a stage.[22] He found he could increase the distance by using a receiving LC circuit tuned to resonance with the Tesla coil's LC circuit,[24] transferring energy by resonant inductive coupling.[22] At his Colorado Springs laboratory during 1899-1900, by using voltages of the order of 20 megavolts generated by his enormous magnifying transmitter coil, he was able to light three incandescent lamps at a distance of about 100 feet (30 m).[5][25] The resonant inductive coupling technique pioneered by Tesla has recently become a central concept in modern wireless power development, and is being widely used in short range wireless transmission systems[22][26] like cellphone charging pads.

The inductive and capacitive coupling used in Tesla's experiments are "near-field" effects,[22] meaning that the energy transferred decreases with the sixth power of the distance between transmitter and receiver,[22][27][28][29] so they cannot be used for long-distance transmission. However, Tesla was obsessed with developing a long range wireless power transmission system which could transmit power from power plants directly into homes and factories without wires, described in a visionary June, 1900 article in Century Magazine; "The Problem of Increasing Human Energy",[30] and he believed resonance was the key. Tesla claimed to be able to transmit power on a *worldwide* scale, using a method that involved conduction through the Earth and atmosphere.[31][32][33][34] Tesla was vague about his methods. One of his ideas was that transmitting and receiving terminals could be suspended in the air by balloons at 30,000 feet (9,100 m) altitude, where the air pressure is lower.[31] At this altitude, Tesla thought, an ionized layer would allow electricity to be sent at high voltages (millions of volts) over long distances.



Light bulb *(bottom)* powered wirelessly by "receiver" coil tuned to resonance with the huge "magnifying transmitter" coil at Tesla's Colorado Springs lab, 1899.

In 1901, Tesla began construction of a high-voltage wireless power station, the Wardenclyffe Tower at Shoreham, New York. Essentially a large Tesla coil intended as a prototype transmitter for a "World Wireless System" that was to transmit both information and power worldwide, by 1904 he had lost funding and the facility was never completed.[33][35] Although Tesla seems to have believed his ideas were proven,[36] he had a history of making claims that he had not confirmed by experiment,[37][38] and there seems to be no evidence that he ever transmitted significant power beyond the short-range demonstrations above.[5][21][24][36][38][39][40][41][42] The only report of long-distance transmission by Tesla is a claim, not found in reliable sources, that in 1899 he wirelessly lit 200 light bulbs at a distance of 26 miles (42 km).[5][36] There is no independent confirmation of this supposed demonstration;[5][36][43] Tesla did not mention it,[36] and it does not appear in his laboratory notes.[43][44] It originated in 1944 from Tesla's first biographer, John J. O'Neill,[5] who said he pieced it together from "fragmentary material... in a number of publications".[45] In the 110 years since Tesla's experiments, efforts by others to achieve long distance power transmission using Tesla coils have failed,[5][22][36][41] and the scientific consensus is his World Wireless system would not have worked.[13][20][21][24][33][36][39][46][47] Contemporary scientists point out that while Tesla's coils function as radio transmitters, transmitting energy in the form of radio waves, the frequency he used, around 150 kHz, is far too low for practical long range power transmission.[21][36][40] At these wavelengths the radio waves spread out in all directions and cannot be focused on a distant receiver.[20][21][36][39][47] Long range wireless power transmission was only achieved in the 1960s with the development of microwave technology.[40] Tesla's world power transmission scheme remains today what it was in Tesla's time, a bold, fascinating dream.[33][39]

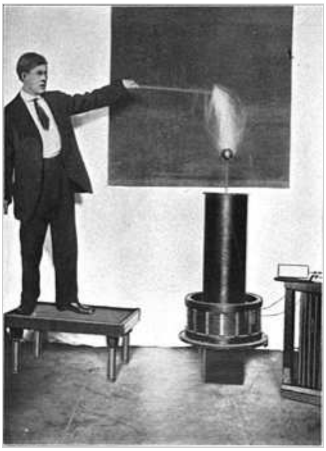
Wardenclyffe tower, a huge Tesla coil built by Tesla at Shoreham, New York, 1901-1904 as a prototype wireless power transmitter. It was never completed

High-frequency electrical safety

The 'skin effect'

The dangers of contact with high-frequency electrical current are sometimes perceived as being less than at lower frequencies, because the subject usually does not feel pain or a 'shock'. This is often erroneously attributed to skin effect, a phenomenon that tends to inhibit alternating current from flowing inside conducting media. It was thought that in the body, Tesla currents travelled close to the skin surface, making them safer than lower-frequency electric currents.

Although skin effect limits Tesla currents to the outer fraction of an inch in metal conductors, the 'skin depth' of human flesh at typical Tesla coil frequencies is still of the order of 60 inches (150 cm) or more.[48][49][50][51][52] This means high-frequency currents will still preferentially flow through deeper, better conducting, portions of an experimenter's body such as the circulatory and nervous systems. The reason for the lack of pain is that a human being's nervous system does not sense the flow of potentially dangerous electrical currents above 15–20 kHz; essentially, for nerves to be activated, a significant number of ions must cross their membranes before the current (and hence voltage) reverses. Since the body no longer provides a warning 'shock', novices may touch the output streamers of small Tesla coils without feeling painful shocks. However, anecdotal evidence among Tesla coil experimenters indicates temporary tissue damage may still occur and be observed as muscle pain, joint pain, or tingling for hours or even days afterwards. This is believed to be caused by the damaging effects of internal current flow, and is especially common with continuous wave, solid state or vacuum tube Tesla coils operating at relatively low frequencies (tens to hundreds of kHz). It is possible to generate very high frequency currents (tens to hundreds of MHz) that do have a smaller penetration depth in flesh. These are often used for medical and therapeutic purposes such as electrocauterization and diathermy. The designs of early diathermy machines were based on Tesla coils or Oudin coils.



Student conducting Tesla coil streamers through his body, 1909

Large Tesla coils and magnifiers can deliver dangerous levels of high-frequency current, and they can also develop significantly higher voltages (often 250,000–500,000 volts, or more). Because of the higher voltages, large systems can deliver higher energy, potentially lethal, repetitive high-voltage capacitor discharges from their top terminals. Doubling the output voltage quadruples the electrostatic energy stored in a given top terminal capacitance. If an unwary experimenter accidentally places himself in path of the high-voltage capacitor discharge to ground, the low current electric shock can cause involuntary spasms of major muscle groups and may induce life-threatening ventricular fibrillation and cardiac arrest. Even lower power vacuum tube or solid state Tesla coils can deliver RF currents capable of causing temporary internal tissue, nerve, or joint damage through Joule heating. In addition, an RF arc can carbonize flesh, causing a painful and dangerous bone-deep RF burn that may take months to heal. Because of these risks, knowledgeable experimenters avoid contact with streamers from all but the smallest systems. Professionals usually use other means of protection such as a Faraday cage or a metallic mail suit to prevent dangerous currents from entering their bodies.

The most serious dangers associated with Tesla coil operation are associated with the primary circuit. It is capable of delivering a sufficient current at a significant voltage to stop the heart of a careless experimenter. Because these components are not the source of the trademark visual or auditory coil effects, they may easily be overlooked as the chief source of hazard. Should a high-frequency arc strike the exposed primary coil while, at the same time, another arc has also been allowed to strike to a person, the ionized gas of the two arcs forms a circuit that may conduct lethal, low-frequency current from the primary into the person.

Further, great care must be taken when working on the primary section of a coil even when it has been disconnected from its power source for some time. The tank capacitors can remain charged for days with enough energy to deliver a fatal shock. Proper designs always include 'bleeder resistors' to bleed off stored charge from the capacitors. In addition, a safety shorting operation is performed on each capacitor before any internal work is performed.[53]

Instances and devices

Magnifier Configurations

Tesla's Colorado Springs laboratory possessed one of the largest Tesla coils ever built, known as the "Magnifying Transmitter". The Magnifying Transmitter is somewhat different from classic two-coil Tesla coils. A magnifier uses a two-coil 'driver' to excite the base of a third coil ('resonator') located some distance from the driver. The operating principles of both systems are similar. The world's largest currently existing two-coil Tesla coil is a 130,000-watt unit, part of a 38-foot-tall (12 m) sculpture titled *Electrum* owned by Alan Gibbs and currently resides in a private sculpture park at Kakanui Point near Auckland, New Zealand.[56]

The Tesla coil is an early predecessor (along with the induction coil) of a more modern device called a flyback transformer, which provides the voltage needed to power the cathode ray tube used in some televisions and computer monitors. The disruptive discharge coil remains in common use as the 'ignition coil'[57][58] or 'spark coil' in the ignition system of an internal combustion engine. These two devices do not use resonance to accumulate energy, however, which is the distinguishing feature of a Tesla coil. They do use inductive "kick", the forced, abrupt decay of the magnetic field, such that the voltage provided by the coil at its primary terminals is much greater than the voltage applied to establish the magnetic field, and this higher voltage is then multiplied by the transformer turns ratio. Thus, they do store energy, and a Tesla resonator stores energy. A modern, low-power variant of the Tesla coil is also used to power plasma globe sculptures and similar devices.

Scientists working with a glass vacuum line (e.g. chemists working with volatile substances in the gas phase, inside a system of glass tubes, taps and bulbs) test for the presence of tiny pin holes in the apparatus (especially a newly blown piece of glassware) using high-voltage discharges, such as a Tesla coil produces. When the system is evacuated and the discharging end of the coil moved over the glass, the discharge travels through any pin hole immediately below it and thus illuminates the hole, indicating points that need to be annealed or reblown before they can be used in an experiment.

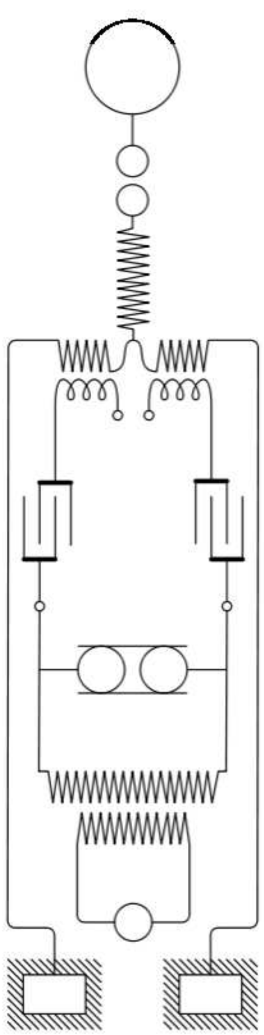
Popularity

Tesla coils are very popular devices among certain electrical engineers and electronics enthusiasts. Builders of Tesla coils as a hobby are called "coilers". A very large Tesla coil, designed and built by Syd Klinge, is shown every year at the Coachella Valley Music and Arts Festival, in Coachella, Indio, California, USA. People attend "coiling" conventions where they display their home-made Tesla coils and other electrical devices of interest. Austin Richards, a physicist in California, created a metal Faraday Suit in 1997 that protects him from Tesla Coil discharges. In 1998, he named the character in the suit Doctor MegaVolt and has performed all over the world and at Burning Man 9 different years.

Low-power Tesla coils are also sometimes used as a high-voltage source for Kirlian photography.[59]

Tesla coils can also be used to generate sounds, including music, by modulating the system's effective "break rate" (i.e., the rate and duration of high power RF bursts) via MIDI data and a control unit. The actual MIDI data is interpreted by a microcontroller which converts the MIDI data into a PWM output which can be sent to the Tesla coil via a fiber optic interface.[60][61] The YouTube video Super Mario Brothers theme in stereo and harmony on two coils (http://www.youtube.com/watch?v=B1O2jcfOylU) shows a performance on matching solid state coils operating at 41 kHz. The coils were built and operated by designer hobbyists Jeff Larson and Steve Ward. The device has been named the Zeusaphone, after Zeus, Greek god of lightning, and as a play on words referencing the Sousaphone. The idea of playing music on the singing Tesla coils flies around the world and a few followers[62] continue the work of initiators. An extensive outdoor musical concert has demonstrated using Tesla coils during the Engineering Open House (EOH) at the University of Illinois at Urbana-Champaign. The Icelandic artist Björk used a Tesla coil in her song "Thunderbolt" as the main instrument in the song. The musical group ArcAttack uses modulated Tesla coils and a man in a chain-link suit to play music.

The most powerful conical Tesla coil (1.5 million volts) was installed in 2002 at the Mid-America Science Museum in Hot Springs, Arkansas.[63] This is a replica of the Griffith Observatory conical coil installed in 1936.



Classically driven configuration.[54]

Later-type driven configuration. Pancake may be horizontal; lead to resonator is kept clear of it.[55]

Related patents

Tesla's patents

See also: List of Tesla patents

- "*Electrical Transformer Or Induction Device*". U.S. Patent No. 433,702, August 5, 1890[64]
- "*Means for Generating Electric Currents*", U.S. Patent No. 514,168, February 6, 1894
- "*Electrical Transformer*", Patent No. 593,138, November 2, 1897
- "*Method Of Utilizing Radiant Energy", Patent No. 685,958 November 5, 1901*
- "*Method of Signaling", U.S. Patent No. 723,188, March 17, 1903*
- "*System of Signaling", U.S. Patent No. 725,605, April 14, 1903*
- "*Apparatus for Transmitting Electrical Energy" (http://www.tfcbooks.com/patents/1119732.htm), January 18, 1902, U.S. Patent 1,119,732, December 1, 1914 (available at U.S. Patent 1,119,732 (https://www.google.com/patents/US1119732)*

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- Gene Koonce, U.S. Patent 6,933,819 (https://www.google.com/patents/US6933819), "*Multifrequency electro-magnetic field generator*". (Filed October 29, 2004; Issued August 23, 2005)[65]

See also

- 833A
- Bifilar coil
- Henry Leroy Transtrom
- List of Tesla patents
- Wireless energy transfer

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External links

- Tesla coil (https://www.dmoz.org/Science/Technology/Electronics/High_Voltage/Generators/Tesla_Coils/) at DMOZ

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