



Take a step toward your new career Find out how you can gain the experience necessary to break into your desired career. Whether you have a dream job in mind, you want to be your own boss, or you're looking for stability and good pay, take your first step here. Do you need to tailor your resume for a job application? Are you worried about your upcoming interview? Learn how to nail each step of the hiring process with our Toolkit. Learn How to Become's 15 Best Job Search Sites Seeking a job? These career sites are a great way to search through positions that can help with everything from entry-level work to career advancement. Check out our listing of... Become Team May 1, 2023 Grad's Guide to Getting Hired The right tools can make all the difference to a recent grad beginning their job search. Learn tips and find resources to maximize your nerves get the best of you on interview day. Learn tips, do's and don'ts to nail your next job interview. Become Team October 5, 2021 Resume Guide The resume has joined the digital revolution. Find out how to revamp yours with the best and most marketable resume trends. Become Team March 10, 2023 Professional Skills and trades are the future of work. Explore paths that align with your long-term career goals. The Baby Boomer generation is living much longer than their predecessors, fueling massive growth in health care jobs, including medical coders. The demand for medical aid eligible. Get your vocational and trade school financial aid questions answered and find scholarships. Vocational training programs offer students the opportunity to pursue a career in the skilled trades. Learn how to pursue vocational training. If you're not sure what you want to do yet, explore some tips and career ideas based on your circumstances and needs. explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' Pi explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' Pi (disambiguation). This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. "Substation" - news · newspapers · books · scholar · JSTOR (May 2025) (Learn how and when to remove this message) Elements of a substation Primary power lines' sideSecondary power lines formerControl buildingSecurity fenceSecondary power lines A 50 Hz electrical substation in Melbourne, Australia, showing three of the five 220 kV/66 kV transformers, as well as high-voltage transformer fire barriers, each with a capacity of 150 MVA. This substation uses steel lattice structures to support strain bus wires and apparatus.[1] A 115 kV to 41.6/12.47 kV 5 MVA 60 Hz substation with circuit switcher, regulators, reclosers and control building at Warren, Minnesota. It shows elements of low-profile construction, with apparatus mounted on individual columns. A substation is a part of an electrical generation, transmission, and distribution system. Substation is a part of an electrical generation, transmission, and the consumer, electric power may flow through several substations at different voltages and lower distribution voltages, or at the interconnection of two different transmission voltages. They are a common component of the infrastructure. There are 55,000 substations in the United States.[2] Substations are also occasionally known in some countries as switchyards. Substations are unattended, relying on SCADA for remote supervision and control. The word substation comes from the days before the distribution system became a grid. As central generation stations became larger, smaller generation, where the generators were housed, and were subsidiaries of that power station. 220 kV/110 kV/20 kV station in Germany Substations may be designed and built by a contractor or alternately all phases of its development may be handled by the electrical utility. Most commonly, the utility does the engineering and procurement while hiring a contractor for actual construction.[3] Major design constraints for construction of substations include land availability and cost, limitations on the construction period, transportation restrictions, and the need to get the substation running quickly.[4] Prefabrication is a common way to reduce the construction cost.[5] For connecting the new substation, a partial outage at another substation may be required, but the utility often tries to minimize downtime.[6] High-voltage substation in Russia step-up transformers[8][9] Interconnection of different power grids[8] Reducing the voltage from transmission to lower-voltage distribution lines.[10] The simplest case.[8][9] Converting from alternating current (AC) to direct current (DC)[8] A transmission substation connects two or more transmission lines.[10] The simplest case.[8][9] Converting from alternating current (AC) to direct current (DC)[8] A transmission substation connects two or more transmission lines.[10] The simplest case.[10] The s is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission station may have transformers to convert between two transmission voltages, voltage control/power factor correction devices such as capacitors, reactors or static VAR compensators and equipment such as phase shifting transformers to control power flow between two adjacent power systems. Minimal HV station in Germany Transmission substations can range from simple to complex. A small "switching station" may be little more than a bus plus some circuit breakers. The largest transmission substations can cover a large area (several acres/hectares) with multiple voltage levels, many circuit breakers, and a large amount of protection and control equipment (voltage and current transformers, relays and SCADA systems). Modern substations may be implemented using international standards such as IEC Standard 61850. Transformer tower in Germany. Medium voltage supply at the front, low voltage output on the side. A distribution substation in Toronto, Canada, disguised as a house, complete with a driveway, front walk and a mown lawn and shrubs in the front yard. A warning notice can be clearly seen on the "front door". Disguises for substations are common in many cities.[11] A distribution substation transfers power from the transmission system to the distribution. The distribution system of an area.[10] It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution. input for a distribution substation is typically at least two transmission or sub-transmission lines. Input voltage may be, for example, 115 kV, or whatever is common in the area. The output is a number of feeders. Distribution voltages are typically medium voltages are typically medium voltage may be, for example, 115 kV, or whatever is common in the area. the local utility. The feeders run along streets overhead (or underground, in some cases) and power the distribution substations also isolate faults in either the transmission or distribution systems. Distribution substations are typically the points of voltage regulation, although on long distribution circuits (of several miles/kilometers), voltage regulation substations, with high-voltage switching, and switching and backup systems on the low-voltage side. More typical distribution substations have a switch, one transformer, and minimal facilities on the low-voltage side. In distributed generation projects such as a wind farm or photovoltaic power station, a collector substation may be required. It resembles a distribution substation may be required. transmission grid. Usually for economy of construction the collector system operates around 35 kV, although some collector systems are 12 kV, and the collector system operates around 35 kV. some special cases a collector substation can also contain an HVDC converter station. Collector substations are Brauweiler in Germany and Hradec in the Czech Republic, where power is collected from nearby lignite-fired power plants. If no transformers are required for increasing the voltage to transmission level, the substation is a switching station. Converter plants, traction current, or interconnected non-synchronous networks. These stations contain power electronic devices to change the frequency of current, or else convert from alternating to direct current or the reverse. Formerly rotary converters changed frequency to interconnect two systems; nowadays such substation without transformers and operating only at a single voltage level. Switching station is a substation without transformers and operating only at a single voltage level. distribution stations. Sometimes they are used for switching station may also be known as a switchyard, and these are commonly located directly adjacent to or nearby a power station In this case the generators from the power station supply their power into the yard onto the generator bus on one side of the yard, and the transmission lines take their power from a Feeder Bus on the other side of the yard. An important function performed by a substation is switching, which is the connecting and disconnecting of transmission lines or other components to and from the system. Switching events may be planned or unplanned. A transmission line or other component may need to be de-energized for maintenance or for new construction, for example, adding or removing a transmission line or a transformer. To maintain reliability of supply, companies aim at keeping the system up and running while performing maintenance. All work to be performed, from routine testing to adding entirely new substations, should be done while keeping the whole system running. Switchyard at Grand Coulee Dam, United States, 2006. This is a 500 kV switchyard. Former high-voltage substation in Stuttgart, Germany, now 110 kV switching station. The 220 kV level is eliminated for grid simplification. 230 kV High-voltage switching station in Washington, United States Unplanned switching events are caused by a fault in a transmission line or any other component, for example: a line is hit by lightning and develops an arc, a tower is blown down by high wind. The function of the switching station is to isolate the faulty portion of the system in the shortest possible time. De-energizing faulty equipment protects it from further damage, and isolating a fault helps keep the rest of the electrical grid operating with stability.[12] Main article: Traction substation Electrified railways also use substations, often distribution substations In some cases a conversion of the current type takes place, commonly with rectifiers for direct current (DC) trains, or rotary converters for trains using alternating current (AC) at frequencies other than that of the public grid. Sometimes they are also transmission substations if the railway network also operates its own grid and generators to supply the other stations. A mobile substation is a substation on wheels, containing a transformer, breakers and buswork mounted on a self-contained semi-trailer, meant to be pulled by a truck. They are designed to be compact for travel on public roads, and are used for temporary backup in times of natural disaster or war. Mobile substations are usually rated much lower than permanent installations, and may be built in several units to meet road travel limitations.[13] In continuous operation in Old Montreal is Canada's oldest substation. It has a facade in clay brick with gray stone ornaments to blend in to its downtown environment. Substation in a castle-like building from the 1910s serves as distribution point next to the Lésna dam. It is one of several hydroelectric stations at the Bóbr river. 15 kV/400 V distribution tower in Poland Substation in the future.[14] Substations may be built outdoors, indoors, or underground or in a combination of these locations.[15][16] Selection of the location of a substation must consider many factors. Sufficient land area is required for installation of equipment with necessary clearances for electrical safety, and for access to maintain large apparatus such as transformers. The site must have room for expansion due to load growth or planned transmission additions. Environmental effects of the substation must be reasonably central to the distribution area to be served. The site must be reasonably central to the distribution area to be served. passers-by, both to protect people from injury by electric shock or arcs, and to protect the electrical system from misoperation due to vandalism. If not owned and operated by a utility company, substations are typically occupied on a long lease such as a renewable 99-year lease, giving the utility company security of tenure.[17] set in wild parkland in North London. The first step in planning a substation layout is the preparation of a one-line diagram, which shows in simplified form the switching and protection arrangement required, as well as the incoming supply lines and outgoing feeders or transmission lines. It is a usual practice by many electrical utilities to prepare one line diagrams with principal elements (lines, switches, circuit breakers, transformers) arranged on the page similarly to the way the apparatus would be laid out in the actual station.[10] In a common design, incoming lines have a disconnector and a circuit breaker. In some cases, the lines will not have both, with either a switch or a circuit breaker being all that is considered necessary. A disconnect switch is used to provide isolation, since it cannot interrupt load currents automatically, and may be used to switch loads on and off, or to cut off a line when power is flowing in the 'wrong' direction. When a large fault current flows through the circuit breaker, this is detected through the use of current transformers. The magnitude of the circuit break from the feeding point. This seeks to isolate the fault point from the rest of the system, and allow the rest of the system to continue operating with minimal impact. Both switches and circuit breakers may be operated locally (within the substation) or remotely from a supervisory control center. With overhead transmission lines, the propagation of lightning and switching surges can cause insulation failures into substation equipment. Line entrance surge arrestors are used to protect substation equipment accordingly. Insulation Coordination studies are carried out extensively to ensure equipment failure (and associated outages) is minimal. Once past the switching components, the lines of a given voltage connect to one or more buses. three-phase electrical power distribution is largely universal around the world. The arrangement of switches, circuit breakers, and buses used affects the cost and reliability of the substations a ring bus, double bus, or so-called "breaker and a half" setup can be used, so that the failure of any one circuit breaker does not interrupt power to other circuits, and so that parts of the substation may be de-energized for maintenance and repairs. Substations, especially for small installations, [18] This single-line diagram illustrates the breaker-and-a-half configuration often used in switchyards of small utilities. In large utilities the double-bus-double-breaker configuration is often preferred. Because of the risk of electrical shock, substations are designed with various safety features. [20] Live conductors and bare equipment are kept separate, either with protected equipment, or using screens or distance.[20] Based on the jurisdiction or company,[21] there are safety standards with minimum required clearance between different live equipment or conductors or between different live equipment or conductors or between different live metal and the ground, which often varies with higher clearance between different live equipment or conductors or between differ generate flashover.[22] To this is added the necessary space for employees to work safely and vehicles to pass.[23] Sometimes it is necessary to work on parts of the substation while energized, but employees must maintain a safe distance of at least 3 metres (9.8 ft).[24] The aim to reduce substation footprints comes into conflict with ease of maintenance enhanced by including gaps where employees can safely work.[25] Underneath a substation, a mat or grid of conductors laid around 0.5 or 0.6 metres (1 ft 8 in or 2 ft 0 in) underground provides grounding.[26][27] This grid, which is typically copper although it may be galvanized iron in some countries,[27] is used to ground circuits that are being worked on to prevent accidental re-energization while workers are in contact with a de-energized circuit.[28] Often, earth rods are driven deeper into the grounding for the lifetime of the substation.[30] Above ground, the grounding conductors may be steel, aluminum, or copper. They must be thick enough to carry the expected current of a fault for 1-3 seconds and remain undamaged.[27] Substation fences, typically at least 2 metres (6 ft 7 in) in height, both protect the public from electrical hazards and also protect the substation from vandalism.[31] Internal fences can also be incorporated to protect employees from areas that are unsafe when energized.[32] Substations generally have switching, protection and control equipment, and transformers. In a large substation, circuit breakers are used to interrupt any short circuits or overload currents that may occur on the network. Smaller distribution stations may use recloser circuit breakers or fuses for protection of distribution circuits. Substations themselves do not usually have a substation nearby. Other devices such as capacitors, and reactors may also be located at a substation. Substations may be on the surface in fenced enclosures, underground, or special-purpose buildings. High-rise buildings may have several indoor substations. Indoor substations. Indoor substations are usually found in urban areas to reduce the noise from transformers, improve appearance, or protect switchgear from extreme climate or pollution. Substations often use busbars as conductors between electrical equipment. Busbars may be aluminum tubing 3-6 inches (76-152 mm) thick, or else wires (strain bus).[33] Outdoor, above-ground substation structures, although other variants are available. Where space is plentiful and appearance of the station is not electrical equipment. a factor, steel lattice towers provide low-cost supports for transmission lines and apparatus. Low-profile substations may be gas insulated switchgear), or use metal-enclosed or metal-clad switchgear at lower voltages. Urban and suburban indoor substations may be finished on the outside so as to blend in with other buildings in the area. A compact substation built in a metal enclosure, in which each item of the electrical equipment is located very near to each other to create a relatively smaller footprint size of the substation. High-voltage circuit breakers are commonly used to interrupt the flow of current in substation equipment. At the time of interruption, current could be normal, too high due to excessive load, unusual due to a fault, or tripped by protective relays prior to anticipated trouble.[34] The most common technologies to extinguish the power arc from separating the conductors in the breaker include:[35] Air at atmospheric pressure (air-insulated switchgear (AIS)), which is the most common worldwide.[36] Air is the visual impact of a larger substation with overhead power lines entering and exiting, which may be unacceptable in scenic or urban areas.[38] AIS requires additional bracing in a seismically active area, and emits more electromagnetic fields and noise than alternative technologies.[39] Gas (gas circuit breaker (GCB) or gas-insulated switchgear (GIS)), most commonly sulfur hexafluoride (SF6) or a mixture of gases including SF6.[36] Although it is the most expensive, these gases are a much more effective insulator than air.[37] GIS require only 10 to 20 percent of the land area as AIS,[40] which can save on land acquisition cost in urban areas,[37] and allow the substation to be built at the exact location where its power is being used in an industrial or urban area—which can be a significant cost savings. On the generation side, GIS can be installed closer to the generator which allows cost savings in cabling, bus duct connections, and civil construction and can increase reliability.[38] GIS can replace AIS if power requirements increase without requiring additional land area.[38] Additionally, GIS is commonly installed in an enclosed building that keeps the equipment protected from pollution and salt.[37][38] Unless the substation is often used for switching, maintenance cost can be very low or even zero for many years.[41] Because SF6 turns to solid around -40 °C (-40 °F), in some climates these circuit breakers require heaters to function in extremely cold weather.[42] SF6 has been used in switchgear since the 1960s.[43] Mineral oil (called OCB for oil circuit breaker) provides a high resistance between the opened contacts, effectively stopping the flow of current.[35] Although oil circuit breakers are suitable for a wide range of voltages, there are suitable for a wide range of voltages. oil becomes contaminated during the suppression of arcs and must be filtered or replaced periodically.[44] Vacuum is a better insulator than air circuit breakers (VCB) are smaller than air circuit breakers and are commonly used in distribution and other switchgear under 35kv.[42] Mixed, including both gas and air insulation. Although it's the least common option[36] it can be useful when an air-insulated substation needs to be expanded but there is very limited location for additional construction.[37] Reclosers are similar to breakers, and can be cheaper because they do not require separate protective relays. Often used in distribution, they often are programmed to trip when the amps exceed a certain amount over a period of time. Reclosers will attempt to re-energize the circuit after a delay. If unsuccessful for a few times, the reclosers will attempt to re-energize the circuit after a delay. as motors, transformers, and some industrial equipment) with their reactive load. [46] Additional capacitor capacity may be needed if dispersed generation (such as small diesel generators, rooftop photovoltaic solar panels, or wind turbines) are added to the system. [47] Capacitors can reduce the current in wires, helping stem system losses from voltage drop or enabling extra power to be sent through the conductors. Capacitors may be left on in response to constant inductive load or turned on when inductive load or turned on when inductive load is increased, such as in the summer for air conditioners. The switching may be remote and can be done manually or automatically.[46] Workers at a substation in Glasgow during World War I, monitoring and recording voltages. The machines on the right are rotary converters. Larger substations have control rooms for the substation equipment. It often contains protective relays, meters, breaker controls, communications, batteries, and recorders that save detailed data about substation operations, particularly when there is any unusual activity, to help reconstruct what happened after the fact. These control rooms typically are heated and air conditioned to ensure the reliable operation of this equipment.[48] Additional equipment is necessary to handle power surges associated with intermittent renewable energy such as dispersed generation from wind or solar.[49] Most transformers lose between 5 and 1.5 percent of their input as heat and noise. Iron losses are proportionate to the square of the current. Auxiliary losses are due to running fans and pumps[50] which is noisy when the transformer is operating at maximum capacity.[51] To reduce noise, enclosures are often built around the transformers are often built around the transformer and can also be added after the substation is built.[51] To reduce noise, enclosures are often built around the transformer and can also be added after the substation is built.[51] To reduce noise, enclosures are often built around the transformer and can also be added after the substation areas or firewalls are built around the transformer to stop the spread of fire.[52] Firefighting vehicles are allowed a path to access the area.[53] Maintenance of substations involves inspections, data collection and analysis, and routine scheduled work. maintenance and predict dangers before they materialize. Infrared technology finds hot spots in the substation where electrical energy is being converted to heat, [54] which indicates a problem and can cause additional damage from the high heat. Dissolved gas analysis can tell when an oil-insulated transformer needs to have the oil filtered or replace, and also detect other issues.[55] Main article: Power-system automation Early electrical substations required manual collection of data for load, energy consumption, and abnormal events. As the complexity of distribution networks grew, it became economically necessary to automate supervision and control of substations from a centrally attended point, to allow overall coordination in case of emergencies and to reduce operating costs. Early efforts to remote control substations used dedicated communication wires, often run alongside power circuits. Power-line carrier, microwave radio, fiber optic cables as well as dedicated wired remote control circuits have all been applied to Supervisory Control and Data Acquisition (SCADA) for substations. The development of the microprocessor made for an exponential increase in the number of points that could be economically controlled and monitored. Today, standardized communication protocols such as DNP3, IEC 61850 and Modbus, to list a few, are used to allow multiple intelligent electronic devices to communicate with each other and supervisory control at substations is one element of the so-called smart grid. ^ "Joint Consultation Paper: Western Metropolitan Melbourne Transmission Capacity" Jemena. Powercor Australia, Jemena, Australian Energy Market Operator. Retrieved 4 February 2016. ^ Anguiano, Dani (10 December 2022). "Attacks on Pacific north-west power stations raise fears for US electric grid". The Guardian. Los Angeles. Retrieved 10 December 2022. ^ Okada 2018, p. 334. sfn error: no target: CITEREFOkada2018 (help) ^ Okada 2018, p. 335. sfn error: no target: CITEREFOkada2018 (help) ^ Okada 2018, p. 341. sfn error: no target: CITEREFOkada2018 (help) ^ Finn 2019, pp. 7 8. ^ a b c d Finn 2019, p. 7. ^ a b Blume 2016, p. 54. ^ a b c Stockton, Blaine. "Design Guide for Rural Substations" (PDF). USDA Rural Development. United States Department of Agriculture. Retrieved 4 February 2016. ^ Steinberg, Neil (13 December 2013). "Lights On but Nobody Home: Behind the Fake Buildings that Power Chicago". Retrieved 14 December 2013. ^ "Transformer Fire Video". metacafe. User Eagle Eye. Retrieved 4 February 2016. ^ Boyd, Dan Rampaul, Glen. "Mobile Substations" (PDF). IEEE Winnipeg PES Chapter. IEEE Power and Energy Society. Retrieved 11 October 2017. ^ Finn 2019, p. 68. ^ Glaubitz et al. 2018, p. 422. sfn error: no target: CITEREFGlaubitz_et_al.2018 (help) ^ Chapman, A. and Broom, R., Electricity Substation Leases: Considerations for Utility Companies, Landowners and Developers, Squire Patton Boggs, originally published by Utility Week, 26 January 2018, accessed 22 August 2023 ^ Donald G. Fink, H. Wayne Beatty Standard Handbook for Electrical Engineers Eleventh Edition, McGraw Hill 1978 ISBN 0-07-020974-X Chapter 17 Substation Design ^ Finn 2019, p. 41. ^ a b Finn 2019, p. 42. ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 46, 53. ^ Finn 2019, pp. 313. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, pp. 34. ^ Finn 2019, pp. 3 314. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Nixon et al. 2018, pp. 314-315. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Finn 2019, p. 65. ^ Blume 2016, p. 69. ^ a b Blume 2016, p. 70. ^ a b c Twomey 2018, p. 12. sfn error: no target: CITEREFTwomey2018 (help) ^ a b c d e Twomey 2018, p. 13. sfn error: no target: CITEREFGlaubitz 2018, p. 363. sfn error: no target: CITEREFGlaubitz 2018, p. 365. sfn error: no target: CITEREFGlaubitz 2018, p. 361. sfn error: no target: CITEREFGlaubitz 2018, p. 363. sfn error: no target: CITEREFGlaubitz 2018, p. 365. sfn error: no target: CITEREFGlaubitz 2018, p. 365 CITEREFGlaubitz2018 (help) ^ a b Blume 2016, p. 72. ^ Nixon et al. 2018, p. 329. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ Blume 2016, p. 77. ^ Nixon et al. 2018, p. 321. sfn error: no target: CITEREFNixon_et_al.2018 (help) ^ a b Nixon et al. 2018, p. 322. sfn error: no target: CITEREFNixon_et al.2018 (help) ^ Finn 2019, p. 62. ^ Finn 2019, p. 63. ^ Blume 2016, p. 88. ^ Blume 2016, p. 88. ^ Blume 2016, p. 89. Wikimedia Commons has media related to Electrical substation. Blume, S.W. (2016). Electric Power System Basics for the Nonelectrical Professional. IEEE Press Series on Power and Energy Systems. Wiley. ISBN 978-1-119-18019-7. Finn, John (2019). "Introduction to Substations. Springer International Publishing. pp. 7-10. ISBN 978-3-319-49574-3. Retrieved from " 71%(17)71% found this document useful (17 votes)34K viewsThe document discusses an internship report submitted by Nisha C at Larsen & Toubro for their B.Tech degree. It includes chapters on the company profile, internship details, reflection notes...SaveSave Internship report presents a comprehensive overview of the operations and structural organization of the Nishat Group, a the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The license terms. Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation. No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Becoming an electrical engineer requires training, commitment, and the willingness to use so much electricity without blowing a fuse. Electrical engineers answer the tough electrical questions and may work on anything from handheld gadgets to massive electrical engineers must consider questions such as: What level of degree should I get to maximize my income? What concentration should I learn to obtain my dream career? Do I have to join an engineering firm or can I work on my own? This comprehensive guide is designed as a resource for individuals interested in the electrical engineer, degree paths, potential salaries and projected career growth for specific subfields. What Does an Electrical Engineer Do? Electrical Engineers use physics, electrical engineers work on anything from small pocket devices that are powered by or produce electrical systems. Engineers use physics, electrical engineers work on anything from small pocket devices that are powered by or produce electrical engineers use physics. systems. Nearly every industry has a place for an electrical engineer, including government, transportation, communications, technology and utilities. Most electrical engineers work in an office or lab setting, but on-site projects and short-term assignments are common. Show More Electrical Engineer Salaries and Job Outlook Salary Facts and Figures Electrical engineers are well-paid for their work. The Bureau of Labor Statistics reports the median annual wage for electrical engineers was \$91,410 in 2014. Engineers was \$91,410 in 2014. year and engineers in the bottom 10 percent can expect to earn an average of \$60,000 annually. The highest earners are located in California, Alaska, Massachusetts, the District of Columbia and Washington state. The map below shows details of the 10th, 50th, and 90th percentile earners for each state. Career Growth and Prospects Electrical engineering jobs are expected to grow at a slower-than-average pace from 2012 to 2022, so picking the right electrical engineering degree is crucial. Engineers who keep up-to-date with industry trends will have an advantage over the competition. Electrical engineering is shifting toward computer systems design and away from traditional manufacturing. Electrical engineers work to build powerful electronics that use computer, cellular and GPS technologies. Constant technol California Connecticut Delaware Florida Hawaii Idaho Illinois Indiana Iowa Kansas Louisiana Maine Maryland Massachusetts Michigan Minnesota Missouri Montana Nebraska Nevada New Hampshire New Jersey New Mexico New York North Carolina South Dakota Texas Utah Vermont Washington State West Virginia Wisconsin Wyoming Steps to Becoming an Electrical engineers hold a bachelor-level electrical engineers hold a bachelor-level electrical engineers hold a bachelor step 1 Earn a bachelor's degree or higher Most employers require that entry-level electrical engineering and Technology (ABET). Bachelor's degree coursework typically includes digital systems design, electrical circuit theory and differential equations. In addition to classroom work, electrical engineering majors can participate in laboratory work and field studies. skills in real-world environments through internships. Electrical engineering students may be able to combine a bachelor's degree and master's degree and 2 Take the Fundamentals of Engineering exam All electrical engineers who work in the utility field must be licensed through the Fundamentals of Engineering (FE) exam. To qualify for licensure, an applicant must have completed a degree from an ABET-accredited engineering program and earn a passing score on the Fundamentals of Engineering (FE) exam. Students can take the FE exam upon graduating with an electrical engineer interns (EIs) until they pass their Professional Engineer (PE) exam. Step 3 Land an entry-level job and gain experience Advancement in electrical engineering is often based on experience and accomplishments. A graduate degree is not required, but many employers prefer their engineering provides an advantage in the field and leads to faster career advancement. Step 4 Take Professional Engineer exam To qualify for the Professional Engineer (PE) exam, EITs must have four years of relevant work experience. Several states require continuing education for professional engineers to keep their engineers to keep their engineers must keep abreast of changes in the field even after earning their PE license. According to a Princeton Review survey, over one-third of electrical engineering degrees at the associate level are also available. All engineering degrees focus heavily on math and science. Classes become more advanced as students progress through their chosen degree plan. Students can choose from multiple electrical engineering degrees at the associate through graduate levels. Use the following chart to explore more of what each electrical engineering degree can offer graduates: Career Goal and/or educational needs Associate Bachelor's Master's Doctorate Online I want to earn my degree on my own schedule. I want to explore cutting-edge research and programs. I'm interested in teaching others about electrical engineering. I'd like to manage large projects involving other engineering. I'd like to manage large projects involving others about electrical engineering. I'd like to manage large projects involving other engineering. bachelor's degree in engineering are in California: UC Berkeley Cal Poly UCLA In-Depth Review of Degree Options Although pre-engineering programs are available at the associate degree level, electrical engineers must earn at least a bachelor's degree, in which they will learn not only electrical theory, but also how to practically use engineering equipment and analyze electrical schematics they will encounter in the field. Additionally, they will study the different applications for electrical engineering degrees, including how to store energy, make computers run, and establish and maintain functioning communication networks. Some engineers choose to get a master's degree or doctorate, especially if they want to supervise projects or teach university courses. Graduate degrees are also an option for students who want to burnish their credentials in an engineering specialization. Associate Degrees Most employers require electrical engineers to hold a bachelor's degree from a school accredited by the Accreditation Board of Engineering and Technology (ABET), but some colleges still offer associate programs in electrical engineering can get a related degree at the associate level through an engineering technology or pre-engineering program. An associate degree will not provide the same job opportunities, but it can help students determine if they want to continue in the field of electrical engineering. Students in an electrical engineering technology program might take some of the following classes: This general education course covers algebraic concepts, including quadratic, polynomial, linear and radical equations. Skills & Knowledge Gained Use mathematical concepts to solve problems Use technological tools for math This course looks at the inner workings of a computer and how operating systems are organized. Skills & Knowledge Gained Understand the internal structure of computers Assemble basic parts of computer This course looks at the inner workings of a computer and how operating systems are organized. electronics systems and circuits work. Students learn about circuit types, electromagnetism, frequency and voltage. Skills & Knowledge Gained Apply electronics principles toward circuits commonly used in electronic devices This course covers data communications between computers, installed software and hardware devices. Content includes coding and decoding, circuit switching and packet switching. Students also learn network protocols and device functions. Skills & Knowledge Gained Design basic network protocols Set up hardware such as printers and scanners so they can communicate with networked computers Bachelor's Degrees A four-year electrical engineering degree prepares students to design and analyze electrical systems. During the course of the degree, students will gain extensive understanding of electrical theory and hands-on experience with circuitry, mechanics, computer programming and thermodynamics. Students to design and analyze electrical systems. engineering or telecommunications engineering. Entry-level math and physics courses are typically prerequisites before students to choose a specialization. As students progress through an electrical engineering bachelor's degree, courses continue to increase in difficulty. A bachelor's degree in electrical engineering from an ABET-accredited program qualifies graduates to take the Fundamentals of Engineering exams. Students must pass these exams to become licensed professional engineering courses offered at the bachelor's level include: This course introduces students to calculate possible effects of engineering decisions, such as maximizing sound data into minimal bandwidth or managing network traffic. Topics include variables, distribution and density functions, conditional probability and weak and strong laws of large numbers. Skills & Knowledge Gained Calculate probabilities when making engineering decisions Analyze potential variables that may affect systems outcomes This course looks at the transfer of energy and matter, including heat, light, electricity and magnetism. Skills & Knowledge Gained Recognize universal physical laws Apply mathematical and computational techniques to engineering experiments and problems Students in this class learn about forces, fields and waves and how electromagnetic currents Understand how transmission lines carry alternate current Use calculus to describe electromagnetic currents. electromagnetic fields are affected by dielectric and magnetic materials This course introduces students to the structure of microprocessors, how they are programmed. Skills & Knowledge Gained Configure microprocessors, how they are used and how they are programmed. interact with external devices Master's Degrees Graduate students often study similar topics as students in a bachelor's program, such as power systems, but graduate courses go far beyond the materials students in a bachelor's level and are much more challenging. Additionally, graduate students typically focus on one specific area of electrical engineering, and must demonstrate their knowledge on that topic by completing a project or writing a comprehensive thesis. Graduate students can move into higher-level jobs involving management of projects or engineering teams. explains how electrical energy is converted to mechanical energy, underlining the importance of electric power to transmit energy systems, including how wind, solar and hydroelectric power are generated. Skills & Knowledge Gained Calculate power flow throughout an electrical system Install and maintain power control equipment, motors and other electrical devices used in manufacturing plants are used in circuitry and effects on their electrical properties. Skills & Knowledge Gained Describe how electrons are transported and how this affects operation of semiconductor devices that use light to interact with other materials, providing them with in-depth knowledge of how they work. Skills & Knowledge Gained Solve optical circuit problems Design optical amplifiers, oscillators, detectors and control circuits This course explores mathematical modeling of linear systems in terms of time and lag controllers. for linear systems using proper techniques Doctoral Degrees Individuals with a master's degree in electrical engineering, which opens up opportunities at the top levels of industry and employment in research or teaching. PhD students spend much of their time completing a research dissertation, but are also responsible for taking coursework in a designated specialization. Many doctoral students teach courses to undergraduate students while earning their degree. ABET provides a list of expected students while earning their degree. degree programs. Doctorate courses in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide master's level and provide mastery in electrical engineering are more complex and difficult than courses at the bachelor's and master's level and provide master's level and provide master's level and provide master's level and provide master skills: Students will have taken hundreds of hours of math courses by the time they receive a doctorate in electrical engineering. ABET asks that doctorate graduates be able to apply their mathematical knowledge to model systems and processes before construction. students should, understand how most electrical devices work and be able make improvements based on what end users need. This requires not just an understanding of software or hardware, but also an appreciation of how both components interact. research processes and electronics. Students conduct experiments on theoretical designs for new electronic systems. As electrical systems continue to grow and expand, engineering is a complicated field, and many people do not understand electrical systems. and business professionals as they work together to improve electrical systems, control systems, control systems, or computer hardware. Most universities allow students to specialize in multiple concentrations depending on course offerings and student desire. Communications Communication from one place to another, via Internet, mobile phones, satellite radio or face-to-face meetings. A specialization in communications covers information theory, wireless networking, noise suppression, compression and security. exams to work in telecommunications and some states require an additional four years of experience before obtaining the title of professional engineer. Designs wireless networks and works with electronic devices to broadcasting equipment to satellite equipment. Maintains equipment necessary for radio and television broadcast. Power systems for commercial, industrial or residential use. Power system engineers design large-scale power systems for commercial, industrial or residential use. different power grids. Designs and improves industrial facilities' electrical grids, provide lightning protection and design area up to code. Uses engineering software and substation construction to design electrical grids, provide lightning protection and design area lighting. Designs, relocates and upgrades transmission lines with fiber optic additions; works with both wood and steel structure designs Electronic Engineers design and test electronic components so that that software work together seamlessly. Uses circuits, microcontrollers and digital signal processors to design and develop $\hat{a} \in \alpha$ controllers and modifies systems for optimal function. Uses advanced understanding of electronic engineering to sell scientific products to businesses; explains product modifications to engineers based on customer needs; trains clients on how to use equipment Computer science and electrical systems and focuses on software-hardware integration. Computer engineers often write the software that makes a computer's components run. Designs computer components, creates blueprints for new computers and updates hardware to work with new software. Designs communication networks to send and receive data via local area network or intranet system linking, secures network data, sources hardware to set up and support the network and installs cables and other network hardware. Earning an Electrical Engineering Degree Online Online degrees provide flexibility for students who cannot or choose not to attend a traditional university. However, not all electrical engineering degrees offer the same program benefits and accreditation. online program: Accreditation Accreditation guarantees the program and school has met required academic standards and allows schools to offer federal financial aid to students. Additionally, graduation from an ABET-accredited program is a prerequisite for professional engineers must be familiar with the latest technology. Online engineering programs should offer technology support, such as smartphone applications or streaming video for online programs provide live video tutoring as well as access to math and writing centers. Online Library and Resources Engineering is a rapidly changing and expanding field. Industry trends can change quicker than curricula and an extensive library can help students keep up to date. and industry journals and magazines. Components of a Successful Career as an Electrical Engineer Skills Electrical Engineer Skills Electrical Engineer Skills Electrical engineers must have a knack for math and science, the ability to analyze systems to understand how they work, the ability to determine how changes affect how system function and knowledge of electrical systems and circuitry. Because electrical engineers often work with team members without an engineers must be able to present complex ideas and relay instructions to others. It is imperative that electrical engineers must be able to apply academic knowledge to new tasks and to keep up with rapid changes in technology. Electrical Engineer Credentials Individuals in an electrical engineering, including: Energy Efficiency Management Certificate: Certificate: Certificate: Certificate in specific fields of engineering, including: Energy Efficiency Management Certificate: Cer program. Electrostatic Discharge Control Technician: Offered by the International Association for Radio, Telecommunications and Electromagnetics for engineering field concentration. Fiber Optics for Traffic System Technician: Offered to city, county and state transportation workers who install and maintain transportation systems. Tools and Technology for Electrical Engineers and tube furnaces. Electrical engineers also work with many common engineering software programs, including: Analytical or scientific software Such as Autodesk Electrical engineers also work with many common engineering software Such as Autodesk Electrical engineers also work with many common engineering software Such as Autodesk Electrical engineers also work with many common engineering software Such as Autodesk Electrical engineers also work with many common engineering software Such as Autodesk Electrical engineers also work with many common engineering software Such as Autodesk Electrical engineering software Such as Autodesk AutoCAD software, Cadence Encounter Test and MAGIC layout editor Development software such as Eclipse IDE software and programmed logic controller (PLC) code-generation software. Object- or component-oriented development software such as Eclipse IDE software and programmed logic controller (PLC) code-generation software such as Eclipse IDE software such as Eclip Engineering professions exist across many skills levels and industries. Here are some quick facts about occupations related to electrical engineering field related to aerospace systems 22% or higher Salary \$86,950 Education and Training: Bachelor's degree in biomedical engineering 3% 7% Salary \$108,430 Education and Training: Bachelor's degree in computer science or engineering discipline; (optional) postgraduate certifications in various hardware or software systems 8% Salary \$59,820 Education and Training: Associate degree in electrical engineering; (recommended) Professional Engineer licensure 3% 7% Salary \$61,580 Education and Training: Bachelor's degree in engineering; (recommended) Professional Engineer licensure 5% Salary \$83,060 Education and Training: Bachelor's or master's degree in mechanical engineers earn? Engineers in related fields are also well-compensated for their education and training: Electrical Engineer and Related Job Salaries '\"Subject\";\"10th Percentile\";\"490th Percentile\";\"490th Percentile\";52600;86960;121530' Related Careers at a Glance Engineers\";52600;86960;139450\"Computer Engineers\";52600;86960;121530' Related Careers at a Glance Become Team Contributing Writer Latest Posts In today's digital age, electricity truly keeps the world running, from basics of maintaining your homes to the more complex systems and keep them functioning smoothly, working on everything from the nation's power grid to the microchips inside your cell phones and smartwatches. "(Electrical engineering) spans areas such as semiconductor devices, electronics, industrial control, power, sensors, wired and wireless communication, computers and signal processing," said Dr. Tim Monk, an

assistant professor of electrical engineering at Southern New Hampshire University (SNHU). "It's the practical use of physics and mathematics to create products that make electrons do useful things." Having worked as an analog and mixed-signal integrated circuit design engineer, Monk brings a wealth of experience to his role at SNHU. He also holds 12 patents and has been published in the field. Electrical engineers design, develop, test and manage the manufacturing of electrical engineering is an immensely broad field with job roles in a dizzying array of industries. From electric power generation and distribution to cars to smartphones, electrical engineers are integral parts of thousands of companies. According to the U.S. Bureau of Labor Statistics (BLS), electrical engineers are integral parts of thousands of companies. managers to ensure projects are completed on time and within budget Conduct precise calculations to establish standards for manufacturing and installation Oversee the production and testing of electrical systems to ensure compliance with specifications and codes "What's common to engineering roles is that you'll end up facing some problem with no known solution. Perhaps something stopped behaving as it usually does, a customer decided to use your product in a new way, you need to improve an existing design or even develop something completely new," said Monk. "There's not a step-by-step procedure that you can follow to address every problem. Instead, engineers use experience, judgment and creativity to move forward." While communication and project management skills are important when applying for electrical engineering jobs, a strong educational and professional foundation is key. Earning an electrical engineering degree may be a great first step to ensuring you are prepared to work in the critical role of an electrical engineer. A master's degree in electrical engineering can also provide further learning and help you to specialize in a specific area, such as electronics development or renewable energy. (A master's degree in electrical engineering currently not available at SNHU.) An MBA in Engineering Currently not available at electronics development or renewable energy. industry. After earning a degree, you can also seek licensure and certification as a professional engineer (PE). Becoming a licensed professional engineer and help you stand out in the applicant pool when becoming an electrical engineer can help you stand out in the applicant pool when becoming a licensed professional engineer can help you stand out in the applicant pool when becoming an electrical engineer and help you join a growing field that is vital to today's technology-driven world.* "There's a spectrum of focus from more theory to more practical skills, though both are important," said Monk. He also stated the importance of having presentation and communication skills in the electrical engineering field. "It's one thing to come up with a great new idea, it's another to convince your boss to use it," Monk said. Entering the field of electrical engineering means that you may not only play an important role in the development of innovative new technology but also have a profound impact on the electrical engineers Work? With so many varied opportunities available, jobs for electrical engineers are continuing to grow.* In 2023, electrical engineers made a median salary of \$109,010 and the field is expected to grow by 5% through 2032, according to BLS.* The continued fast-paced growth and advancement of technology means that electrical engineers with a strong background in electronics and computer systems will be in demand for research and development of new technologies, according to BLS.* "Electrical engineers can get jobs designing products, testing pr writing skills, according to BLS. Developing Renewable Electrical Power Electrical engineers can work in the development, design and management of the world's electrical power systems. Today, that includes a growing number of jobs in the evolving renewable energy field.* engineering," said Monk. "Electrical engineers have a lot to contribute to recent pushes in clean energy and electric vehicles and the evolution of the electrical grid." A 2023 report from the International Energy Agency (IEA) found that renewables — including sources such as solar, wind and hydropower — are the largest energy source in 57 countries (IEA PDF Source). By 2028, it's expected that 68 countries will have renewable energy grows, so, too, do jobs for electrical engineers, who work to design, build and manage electrical power systems.* According to the 2023 U.S. Energy and Employment Jobs Report (USEER) the energy work force added nearly 300,000 jobs from 2021 to 2022, which was 3.8% growth.* Powering Technology Another important role of electrical engineers is in the development of the computers, smart phones and more advanced technology that power your personal and professional lives. "We've seen waves of devices spread to most of the world, first with PCs (personal computers) and now smartphones owned by most people," Monk said. "The continuing improvement of technology will enable new electronic devices." The use of technology has continued to grow and evolve in recent years, creating many unique job opportunities for electrical engineers.* According to a 2023 Pew Research report, more than 97% of people ages 18-49 are smartphone owners. In the professional world, automated technologies continue to boom, from robot-assisted surgery to self-driving cars that may one day transport us around major cities. In fact, according to a 2023 report from the International Federation of Robotics (IFR), the total number of service robots sold for professional use was over 158,000 units. This is a 48% increase from 2021. This growth of digital technology would not be possible without the innovative work of electrical engineers, who design and develop the electrical components that power these machines. Electrical engineering continues to evolve as the world does. Monk said the field is broad and all about leveraging our understanding of electricity for the good of humanity. *Cited job growth projections may not reflect local and/or short-term economic or job conditions and do not guarantee actual job growth. Actual salaries and/or earning potential may be the result of a combination of factors including, but not limited to: years of experience, industry of employment, geographic location, and worker skill. Danielle Gagnon is a freelance writer focused on higher education. She started her career working as an education reporter for a daily newspaper in New Hampshire, where she reported on local schools and education policy. Gagnon served as the communications manager for a private school in Boston, MA before later starting her freelance writing career. Today, she continues to share her passion for education as a writer for Southern New Hampshire University. Connect with her on LinkedIn.