**Electrician Thesis, NFPA 241, Construction Safety Standards**

Durham Tech; Electrical Systems Technology

UNLV; Construction Management and Electrical Engineering

UC San Diego; Electronic Circuits and Systems (EC78)

**NFPA 241: Standard for Safeguarding Construction, Alteration, and Demolition Operations**

1. Fire Safety, NEC Electrician Codes, National Electrical Code
2. General Construction Safety, US General Contractor

**Durham Tech; Electrical Systems Technology**

This curriculum is designed to provide training for persons interested in the installation and maintenance of electrical systems found in residential, commercial, and industrial facilities.

Coursework, most of which is hands-on, will include such topics as AC/DC theory, basic wiring practices, programmable logic controllers, industrial motor controls, applications of the National Electric Code, and other subjects as local needs require.

Graduates should qualify for a variety of jobs in the electrical field as an on-the-job trainee or apprentice assisting in the layout, installation, and maintenance of electrical systems.

**Durham Tech; Electronics Engineering Technology**

The Electronics Engineering Technology program provides theory and hands-on practical training in repairing electronic equipment. Students are trained to use measurement tools such as digital multimeters and oscilloscopes. Circuit construction techniques include printed circuit board fabrication and both surface-mount and through-hole component soldering. Students learn to repair any type of electronic equipment including computers, stereos, and hand-held microprocessor equipment.

Graduates should qualify for employment as electronics engineering technician, field service technician, instrumentation technician, maintenance technician, electronic tester, electronic systems integrator, bench technician, and production control technician.

**UC San Diego; Department of Electrical and Computer Engineering**

**Electronic Circuits and Systems (EC78)**

The Department of Electrical and Computer Engineering (ECE) admits students to graduate studies through either the M.S. or Ph.D. programs. ECE offers graduate programs leading to the M.S. and Ph.D. degrees in electrical engineering with specializations in each of the following areas: communication theory and systems; computer engineering; electronic circuits and systems; electronic devices and materials; intelligent systems, robotics and control; magnetic recording; photonics; radio and space science; and signal and image processing. In addition, there are interdepartmental curricula in advanced manufacturing, applied ocean sciences, and materials science.

**UNLV, Master of Science - Construction Management**

The Master of Science in Construction Management (M.S.C.M.) degree provides graduate-level study for those seeking mid- and upper-level management positions in the construction industry or continued study for a doctorate. Students with bachelor's degrees in construction management, engineering, science, architecture and business, etc. are invited to apply. MSCM students should follow the graduate rules and milestones of the program in the Civil & Environmental Engineering and Construction Graduate Student Handbook.

**UNLV, Electrical Engineering**

The Department of Electrical and Computer Engineering at UNLV offers a program leading to the Ph.D. degree in Engineering in the Field of Electrical Engineering. Specific major areas of study currently available include: Communications, Computer Engineering, Control System Theory, Electromagnetics and Optics, Power Systems, Signal Processing, and Solid State Materials and Devices. One may be admitted to the Ph.D. program by one of two mechanisms. The Conventional Option requires the student to complete a M.S. Degree in Electrical and Computer Engineering. The Direct Ph.D. Option allows those undergraduates with outstanding undergraduate backgrounds to enter the Ph.D. program without having to complete a M.S. Degree in Electrical and Computer Engineering. All requirements leading to a Ph.D. are still required beyond the B.S. Degree in Electrical and Computer Engineering excluding the completion of a Master thesis.

1. Voltage- (V) J/C, 1V; potential difference, potential to do work in a wire, electromotive force, the force moving the current, Volt, V; a measure of potential energy --the amount of energy "stored" in an object; a potential energy of one joule per coulomb of charge (a joule, like a coulomb is just an arbitrarily defined unit of energy); 1.5 volt battery, for each 1 coulomb, can do 1.5 joules of work before reentering the other side of the battery, gives off 1.5 joules of light and heat, connected to a light bulb
2. Current- (I) C/S, 1A; a flow of electric charge in a circuit, the rate of flow is measured in Amperes, A; a current exists when one charge is in motion relative to the other; the amount of charge that passes through the wire; the number of coulombs of charge passing by that point per second; a flow of 1 coulomb per second, also written as 1A; the greater the amount of voltage applied in a wire, the greater the current that will flow in that wire

-electric current (I) is the quantity of charge (Q) that passes through a given area in a specified time (t); I=Q/t (in Amps)

1. Resistance- electrical resistance to current moving in a circuit, Ohm, Ω
2. Power Dissipation- the amount of potential energy converted to heat, P=(I)(V), I²R

-V=IR, V=AΩ

1. Coulomb- The SI (International System of Units) unit for charge; 6,250,000,000,000,000,000 electrons is the equivalent of negative one coulomb of charge
2. Resistor- (R), resistive circuit, a resistor is a passive electrical component with the primary function to limit the flow of electric current
3. Conductor- copper, allow electric charge to be moved ("conducted") through the material when an electric force is applied
4. Inductor- (L), Henries, reactive device/element, energy storing device, a device that stores energy in a magnetic field; inductance, Henrys
5. Capacitor- (C) Farads, reactive device/element, energy storing device, a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals; the ability of a capacitor to hold charge is called its capacitance, C; The SI unit of capacitance is the farad, 1 farad is equal to one coulomb per volt

-Q = CV, where Q is the charge stored in the capacitor, C is the capacitance, and V is the voltage

1. Induction- creation of charge as a result of a changing magnetic field through a wire loop is called induction, a current is "induced" in the wire
2. Impedance- the effective resistance of an electric circuit or component to alternating current, arising from the combined effects of ohmic resistance and reactance
3. Resistive Circuits- have resistors
4. Reactive Circuits- have capacitors and inductors
5. Impedance- ratio of phasors of voltage and current; Z = V/I
6. Transfer Function- H(ῳ) Output Phasor/Input Phasor; In engineering, a transfer function of an electronic or control system component is a mathematical function which theoretically models the device's output for each possible input
7. Parallel Resistors- same voltage drop
8. Series Resistors- same current, No Choice; resistance increases, christmas lights
9. Voltage Divider- series resistors, because the voltage across the second resistor is less than the power-supply voltage
10. Effective Resistance- just add the resistances in series
11. Frequency Spectrum- plot of Amplitude v. Frequency
12. RC Circuit- Resistors and Capacitors
13. RLC Circuit- Resistors, Inductors, Capacitors
14. Bode Plot- In electrical engineering and control theory, a Bode plot is a graph of the frequency response of a system. It is usually a combination of a Bode magnitude plot, expressing the magnitude of the frequency response, and a Bode phase plot, expressing the phase shift.
15. Frequency- The rate at which the voltage changes in AC Power; The outlets that you plug your computer, television, and other devices into are generally 110V AC outlets with a frequency of 60Hz. (The frequency is determined by the equipment used to generate the electricity.); AC Voltage varies sinusoidally with a frequency, DC Voltage is constant over time

**DC Analysis**

***Current, Amps, A***

I=Q/t

I(t)=dQ(t)/d(t)

***Voltage, Voltage, V***

V=energy/charge J/C

***Power and Energy, Watts, W***

i=dq/dt

v=dw/dt

p=dw/dt (IV)

Power Sum Generated = 0

**Resistance and Ohm’s Law**

R=pL/A; area, length, (p) Resistivity, (R) Resistance

p metals = to Ωm

p rubber = to Ωm

V/A, volts, amps, (V/I), Ω ohms

G(conductance) = 1/R = σA/L (σ) conductivity

A/V, amps, volts, siemens, ℧ mhos (I/V)

V=IR

**Kirchhoff’s Voltage Law**

-parallel components have same voltage

, sum of voltages in loop =0

-w/parallel components (same voltage), w/current source (not zero voltage), w/open loop

**Kirchoff’s Current Law**

-series components have same current

=

-sum of currents leaving, and sum of currents entering the node

-sum of currents leaving and entering node = 0

**Series and Parallel Resistance (Equivalent Resistance)**

Resistors in Series = Req = R1 + R2

Req =

Resistors in Parallel =

Resistors in Parallel, shorted resistors, Req=0

**Voltage Divider Law**

V2 = Vs

2 resistors in series, different voltage, same current

**Current DIvider Law**

I2 = Is

2 resistors in parallel, different current, same voltage

**Mesh Analysis**

KVL = , solve for mesh currents

**Node Analysis**

, solve for node voltages

**Thevenin Equivalent Circuits**

Vth = (Rth)(Isc), resistor in series

1. Vth= open circuit across a-b and find Vob=Vth
2. Isc= short circuit across a-b and find Isc
3. Rth= circuit resistance with voltage sources shorted and current sources open circuited (when no dependent sources are present)
4. Zero out sources; Vth=0, Isc=0

***Maximum Power Transfer***

PL=(Vab) (I)

=(Vab) (Vab/RL)

=(Vth)

**Norton Equivalent Circuits**

Vth = (Rth)(Isc), resistor in parallel

**Linearity and Superposition**

Superposition Property: A) f(ai) = af(i); scaling factor

B) f(i1 + i2) = f(i1) + f(i2); additive property

Vo= sum of corresponding outputs for each Vs

1. Zero all sources but one, and find the output to that source
2. Repeat the procedure for each source
3. Sum the corresponding outputs

**Resistors in Sensors**

Voltage Divider Law

Vo= Vs

-sensor calibration: physical quantity - Vo relationship

**Wheatstone Bridge**

Voltage Divider Law

-if Vab = 0, then Va=Vb

Vs = Vs

=

=

**Capacitors**

q=CV, QV Characteristic

i=C, IV Characteristic, Passive Convention

(C); Capacitance, Farads

(q); charge, coulombs

(v); voltage, volts

-plate capacitor, C=

**Series and Parallel Capacitors**

Cnew= = 2C C=

ik= Ck

1. Parallel Capacitors; Series Resistors, KCL, Ceff=
2. Series Capacitors; Parallel Resistors, KVL,

**Inductors, Henrys**

L=

1. l; length; A=core area
2. N= number of turns of wire
3. = permeability of core material

**IV Characteristic of Inductors, Passive Convention**

V=L; (i) amps, (L) Henrys, (v) volts

**Series and Parallel Inductors**

Lnew= = 2L

-v= Leff

1. Parallel Inductors- Leff par, , Parallel Resistors
2. Series Inductors- Leff series, , Series Resistors

**Energy in Reactive Elements**

***Capacitor Energy, Direct Method***

-w(t)= ½ C(t)

-(C) Farads, (v) volts, (w) joules

***Inductor Energy, Direct Method***

-w(t)= ½ L

-pabs=

-psup= -

**DC Behaviour of Reactive Elements**

v= L, Inductors, short circuits

i= C, Capacitors, open circuits

**Continuity in Reactive Elements**

-unit stop function, heaviside function

1. Voltage is continuous in capacitors
2. Current is continuous in inductors

**Switching with Reactive Elements after DC**

***SPST, Single-Pole Single-Throw Switch***

1. Initially closed, opens at t=0
2. Initially open, closes at t=0

***SPDT, Single-Pole Double-Throw Switch***

1. Node (a) is connected to node (b) for t<0
2. Node (a) is connected to node (c) for t>0
3. The change is assumed to be instantaneous

**First-Order RC Circuits**

1. i= C, IV Relationship for Capacitor
2. Thevenin Equivalent Circuit

***Solution for the Standard Form***

+y(t)= K

τ = Rth C; Kτ= Voc

**First-Order RL Circuits**

1. v=L, IV Relationship for Inductor
2. Norton’s Equivalent Circuit

**Intro to AC Analysis**

DC Analysis, constant inputs

AC Analysis, sinusoidal inputs

1. Resistive Circuits, resistors
2. Reactive Circuits, capacitors and inductors,has phase change, the input has a different phase than the output, a different angle, a difference in the 0 Crossing

-v(t)= Vm cos(wt + θ)

-Vm= amplitude

-Period= Tsec

-Frequency (Hz)= f=

-Frequency rad/sec= w= 2πf

-Phase Angle= θ= -360 degrees

=

-if the output is shifted to the right from the input, θ is negative, the output phase lags the input phase

-sin(wt)= cos (wt -90)

-(-sin) (wt)= cos (wt +90)

**Phasors**

***Complex Numbers***

j= , c= a + jb

-V(t) = Vcos (wt + θ) voltage

Polar: V= V∠θ Rectangular: V= a +bj

-I(t)= Icos (wt + θ) current

Polar: I= I∠θ Rectangular: I= a +bj

1. adding/ subtracting phasors: use rectangular form
2. multiplying/ dividing phasors: use polar form

**Impedances**

-impedance: ratio of phasors or voltage and current

Z==

Ohm’s law: V=ZI

Zc= ; impedance of capacitor; current leads voltage

ZL= jwl; impedance of inductor; current lags voltage

ZR=R; impedance of resistor; frequency invariant

**AC Circuit Solution Using Impedance Method**

1. Redraw circuit, replacing:
2. Sources with their phasors
3. Components with their impedances; resistors, capacitors, inductors
4. Use circuit analysis methods to solve the circuit, treating impedances like complex resistors; voltage divider law, node analysis, etc.
5. Convert the output phasor to its sinusoidal equivalent

V∠θ → Vcos (wt + θ)

**Transfer Functions**

-to find an input-to-output relationship for a circuit that holds for all input frequencies

x(t)= Ain cos (wt + θin)

y(t)= Aout cos (wt + θout)

H(w)= = = = ∠θout - θin

|H(w)|= ∠H(w)= θout - θin

Aout= |H(w)|Ain θout= ∠H(w) + θin

H(w)=

|H(w)|=

∠H(w)= -(RCw)

**Frequency Response**

-frequency spectrum- plot of amplitude v. frequency

-frequency response- plot of transfer function v. frequency

1. Frequency, rad/sec
2. Frequency, Hz

**Frequency Response Linear**

1. Frequency spectrum
2. Transfer functions; RC Circuit, H(w)=

**Bode Plots**

-20 log (x)

-if = 20 log (|H(w)|) then |H(w)| =

**Bode Plot of RC Circuits**

-corner frequency, Wc= rad/sec

**Bode Plot of RLC Circuits**

-corner frequency, Wc= rad/sec

**Lowpass and Highpass Filters**

-analog filter

-lowpass, output voltage over capacitor for transfer function

-highpass, output voltage over resistor for transfer function

1. Lowpass filter; bandwidth (Wb), passband region, passband gain (G)
2. Highpass filter; corner frequency (Wc), passband region, passband gain (G)

**RLC Circuits**

-corner frequency, Wc=

|input| x |H| = |Output|

+ =

**Bandpass and Notch Filters**

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**Power Module**

**Root Mean Square**

-average of a sinusoid, =

frms=

vrms= =

**Power Factor**

-p(t)= v(t) i(t)

Pave= (Vrms) (Irms)

**Complex Power**

S= ½ VI\*

S= ∠θv - θi

**Power Triangles**

1. Power Angle; θ= θv - θi
2. Power Factor; cosθ
3. Average (Real) Power; P= (Vrms) (Irms) cos(θ) Watts, W
4. Reactive Power; Q= (Vrms) (Irms) sin(θ) Volt-Amperes Reactive (VAR)
5. Apparent Power; |S|= (Vrms) (Irms) Volt-Amperes (VA)

**AC Power Transfer, Maximum Power Transfer**

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**Transformers**

-relationship of magnetic field and current

1. Ampere’s Law; as current flows through a coil it generates a magnetic field
2. Faraday’s Law of Induction; a changing magnetic flux leads to a voltage
3. Linear Transformer Model
4. Used primarily for communications applications
5. Uses impedances for analysis
6. Ideal Transformer Model
7. Used primarily for power transfer
8. Uses voltages and number of coil turns

**Linear Transformer Model**

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**Ideal Transformer Model**

-coefficient of coupling

-relationship between mutual induction and self inductances

M=K; K=1, L1=L2=∞

V1/N1=V2/N2; N1i1=N2i2

**Linear Variable Differential Transformers, LVDT**

-amplitude shows displacement

-phase shows direction

**Electronics, Transistors and Diodes**

**Operational Amplifiers and Ideal Behavior**

-specialized circuit made up of transistors, resistors, and capacitors fabricated in an integrated chip

-active devices, has its own power supply

-passive devices, does not have its own power supply

**Buffer Circuit**

-used to boost power without changing voltage waveform

**Basic Op-Amp Configurations**

***Non-inverting Amplifiers***

Vo= Vin

Vo= (G) (Vin); Gain (G)=

***Inverting Amplifier***

Vo= Vin; Vo=(G) (Vin)

***Difference Circuit***

Vo= (V2-V1)

***Summing Amplifier***

Vo= G1V1 + G2V2

G1= ; G2=

**Differentiators and Integrators; w/capacitors**

***Differentiator Circuit***

Vo= -RC

***Integrator Circuit***

Vo=

**Active Filters**

***Limitations of RLC Passive Filters***

1. Depletes Power
2. No Isolation

**First-Order Lowpass Filters**

***First-Order Filter***

H(w)=

Bandwidth= = 1/τ

DC Gain= H(0)=

***First-Order Inverting Lowpass Filter***

Vo= Vin

***Frequency Characteristics of LP Filter***

H(w)=

|H(w)|=

∠H(w)= 180 - arctan(RfCfw)

DC Gain= = H(0)

Bandwidth= =

***First-Order Lowpass Configurations***

1. Noninverting, isolation at the input; DC Gain =1
2. Noninverting, isolation at the output; DC Gain =1
3. Inverting, isolation at output and input; DC Gain=

**First-Order Highpass Filters**

***Inverting Highpass Filter Configuration***

Vo= Vin

***Frequency Characteristics of Highpass Filter***

H(w)=

|H(w)|=

∠H(w)= -90° -arctan(R1Cw)

Corner Frequency= =

**Cascaded First-Order Filters**

***Transfer Functions in Hertz f***

**Lowpass** **Highpass**

H(w)= H(w)=

Bandwidth= = Corner Frequency= =

DC Gain= H(0)= Passband Gain= =

(f)= (f)=

Hcascade= = x = x

K=()

=

Q, Quality Factor=

BW=

**Second-Order Filter Transfer Functions**

(f)= (f)=

(f)= K (f)= K

1. Butterworth, Q= , Maximally Flat
2. Chebyshev, Q >

**Op-Amp Second-Order Filter Circuits**

1. Sallen-Key Lowpass Filter;
2. Sallen-Key Highpass Filter;

**Notch Filters**

= K = K( + )

2nd HP 2nd LP

**Active Filtering**

***THD, Total Harmonic Distortion***

THD= x 100%

**PN Junction Diodes**

1. Diode cathode; N-Type Region, phosphorous, extra electrons
2. Diode anode; P-Type Region, boron, holes

**Models of Diode Behavior**

1. Ideal Diode Model
2. Ideal Diode and Voltage Source Model
3. Ideal Diode and Voltage Source and Resistor Model

-forward bias, reverse bias, breakdown regions

**Assumed States Method**

1. Identify all possible diode state combinations
2. Analyze each state by replacing the diodes with the corresponding open or short
3. Determine which state is consistent

On: >0

Off: >0

Diode On; short circuit, forward bias

Diode Off; open circuit, reverse bias

**Half-Wave Rectifiers**

-current only flows from anode to cathode of diode when forward biased

Vout= 1) Vin Vin>0; 2) 0 Vin ≤ 0

Vout= 1) Vin Vin>-Vf 2) -Vf Vin ≤ -Vf

**Full Wave Rectifiers**

-rectifier; a non-linear device that moderates an input voltage such that the output voltage is greater than or less than a threshold value

**Voltage Transfer Characteristics, VTCs**

-VTC, a graphical description of the behavior of a nonlinear circuit; a plot of output voltage vs. input voltage

**AC to DC Conversion**

-AC used in power transmission

-DC used to power electronics

-diode rectifiers are used in converting AC to DC

**DC Power Supply Components**

1. AC Source; 60 Hz, 120vAC; 120vRMS 60 Hz sine wave
2. Transformer; steps voltage up or down
3. Rectifier; introduces DC component
4. Low-pass filter capacitor; reduces AC component to smooth output
5. DC output

-larger filter capacitors which result in larger time constants result in a smoother output voltage or smaller ripple voltage

***Time Constant; τ= RC***

1. Larger time constant; slower discharge
2. Smaller time constant; faster discharge

***Output Voltage Level***

-for a sine wave; Vpeak= Vrms x

= Vpeak - 2Vf

**Diode Limiters**

-limiter, clipper; a non-linear device that limits the output voltage to a particular level

**Voltage Regulators**

-Ideal DC Voltage Regulator; a device that maintains a constant DC output voltage regardless of variations in input voltage or load

Line Regulation; ΔVout/ΔVin= 0

Load Regulation; ΔVout/Δ=0

**Envelope Detector Circuits**

***Amplitude Modulation***

1. Carrier; c(t)= Acos()
2. Message; m(t)= kcos()
3. Signal; [1+ kcos()] Acos()

**MOSFET Physics**

-drain, source, gate, used as switches, constructed from doped semiconductor material

**MOSFET Switches**

-NMOS, PMOS, CMOS

**CMOS Logic Gates**

-NOT, AND, NAND, OR, NOR

**MOSFET Characteristics**

-cutoff region, linear/triode region, saturation region

K= transductance parameter, units of A/

= threshold or turn on voltage, minimum value of for to flow

**Common Source Amplifier DC Analysis**

=0, Gate Current

= , Drain Current, Source Current

**Common Source Amplifier AC Analysis**

***Small Signal Analysis***

= 2; transconductance

= 1/

=

**Bipolar Junction Transistor**

-PN; anode and cathode

-NPN BJT; collector, base emitter

1. Bipolar; both positive and negative charge carriers participate in the operation of the device
2. Junction; 2 PN Junctions, between collector and base, and base and emitter
3. Cutoff region; =0 (Off)
4. Saturation region; >0 (On)
5. Active region; amplifier
6. Reverse active region

**BJT Terminal Characteristics**

β= Base to collector current gain, typical value = 100

α= Emitter to collector current gain, typical value = 0.99

**BJT Curve Tracer**

***Measured Output Characteristics***

= -

=

***Measured Transfer Characteristics***

=

=

**BJT Switch**

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The terms electrical and electronic can be defined differently. In this sense, electrical applies to devices, or circuits containing devices, like resistors and capacitors, whose characteristics are fixed, whereas electronic applies to devices, or circuits containing devices, like transistors and diodes, whose characteristics, like resistance, can change according to applied voltages and currents.

**Voltage**

-charge flow, charged particles exert a force on other charged particles, this force per unit charge is called an electric field, charges flow because their electric field exerts forces that push each other

-voltage is the energy either gained or lost per coulomb of charge; V = dw/dq

-current is dq/dt

-power is dw/dt

-voltage = energy (Joules)/charge (Coulombs)

-negative voltage, gained energy; positive voltage, lost energy

-voltage is always measured from a reference point, voltage measurements are relative

-positive power is consumed, downhill, positive to negative, negative power is generated, uphill, negative to positive

-power is the rate of charge of energy and energy is always conserved, so the sum of power generated and consumed in a system is always 0

**Fundamentals of Electricity**

-electronics, electrical circuits

-electric force works on 2 or more electric charges, positive charges and negative charges

-gravitational force acts on 2 or more masses

-magnetic force

-Unlike masses, which always exert an attractive gravitational force on each other, electric charges can exert attractive or repulsive electrical force, depending on which types of charge are involved. Specifically, like charges repel one another, and unlike charges attract one another. Objects without any charge, however, neither experience nor exert an electric force.

-Electronics, or electrical circuits, use the electric force and the properties of different materials, which are composed of various atoms, to perform a variety of functions, such as: creating light, displaying the time, performing complex calculations, displaying an image on a screen.

-Electrical circuits is the study of how an arrangement of conductors and insulators (and, sometimes, semiconductors) behaves when an electric force is applied.

-Solid-state electronics means semiconductor electronics: electronic equipment using semiconductor devices such as transistors, diodes and integrated circuits.

**Power Supplies and Simple Circuits**

-Electronic devices operate by applying voltages that create electric currents through various components. These currents can perform a number of functions: for example, they create heat on an electric range (stove), they create light in a light bulb, and they carry information from point to point in a processor. So, how do we get a voltage so we can perform these functions? The answer is what we can broadly call power supplies.

-An electric power supply is a device or system that converts some form of energy into electrical energy. For example, a battery converts chemical energy to electrical energy by way of chemical reactions that create a voltage across the two terminals (one of which is labeled "+" and the other "-").

-In the case of your electric utility company, the power plant burns coal or uses nuclear fuel to turn a turbine that, through the use of magnets, generates a voltage that power lines carry to your home. Solar panels convert the energy in light to electrical energy.

-Whatever the source, a power supply converts some form of stored or otherwise available energy into electrical energy. (According to a fundamental tenet of physics, energy is neither created nor destroyed--it can only change forms.)

-a 1.5V battery--this is the potential energy difference between the two battery terminals per coulomb of charge

-simple electrical circuit; where the two terminals of a power supply (battery, for example) are connected to each other; An electrical circuit is a closed loop through which current can flow

-If we can "break" and "unbreak" the circuit at will, then we can turn on and off the flow of charge: in other words, we've introduced a switch into the circuit. Note that when the switch is closed (connecting the wire), the configuration is called a closed circuit. When the switch is open, it is called an open circuit

-by "breaking" the circuit, we can control whether current is allowed to flow. This useful approach allows us to turn lights on and off at wall switches, for instance

-current as the flow of positive charge from the positive (positively charged) terminal to the negative (negatively charged) terminal

-current only flows when there is a conducting path from a higher voltage (the positive terminal of the power supply) to a lower voltage (or ground-the negative terminal)

**Resistor Circuits and Ohms Law**

\*\*-electronic circuits use resistors and Ohms Law to charge power supplies

-Determine how much heat is produced in a resistor relative to its voltage and current

-placing a conductor (a wire, for instance) across the terminals of a battery (a type of power supply) will quickly deplete the stored energy. But what if we place some object or device in the circuit that "resists" the current flow? That is, we want to use the electrical potential energy to do some kind of useful work. Such a device is called a resistor because it resists or impedes the flow of current through the circuit.

-perfect conductors: they do not in any way resist or impede the flow of charge. We can therefore logically deduce that the voltage at any point in a continuous conductor relative to ground is the same, regardless of its shape or length. By convention and for simplicity, we'll generally say that ground is 0V (just as we might say the physical ground around us is measured as 0 meters). Thus, in the case of the 1.5V battery shown below, everywhere on the top wire is at 1.5V relative to ground, and everywhere on the bottom wire is 0V.

-A resistor circuit is almost exactly analogous to this situation; the liquid layer converts some of the gravitational potential energy to heat via friction, like meteors through Earth’s atmosphere falling to the Earth; Instead of a vacuum and a liquid, we have a conductor and a resistor. In a (perfect) conductor, charge flows freely, and its movement is unimpeded. In a resistor, however, the flow of charge is impeded, resulting in the creation of heat as charged particles (electrons) "bump" into atoms, causing them to slow down. The result is that some of the electrical potential energy is converted to heat

-The extent to which the resistor impedes the flow of charge is a parameter called resistance, which is often expressed as R. Recall that we said a higher voltage generally produces a higher current through a circuit. Conversely, a higher resistance generally reduces the amount of current through a circuit more than a lower resistance

-The units of resistance are ohms (written as Ω). One ohm is the same as one joule-second per square coulomb

-Because charge loses potential energy as it flows through a resistor, the voltage across that resistor is called a voltage drop

-Power Dissipation; when charge flows through a resistor, it loses potential energy by way of heat. Thus, when you connect an incandescent light bulb to a power supply (either a fixture such as a lamp or batteries in a flashlight), the filament in the bulb (nothing but a wire resistor) heats until it glows, creating light. As it turns out, the amount of potential energy converted to heat--also called power dissipation

-power dissipation is expressed as joules per second, which we also call a watt. Thus, for example, a 100-watt light bulb converts 100 joules per second of potential energy into heat, causing the filament in the bulb to glow and illuminate its surroundings

-Ohms Law, if you 2 of the values associated with the lode in a circuit, you can calculate the other value

**Resistor Networks**

-Circuits with more than one resistor are sometimes called resistor networks

1. Parallel resistors, current divider- same voltage, current depends on the resistance; the current entering any particular point of the circuit must generally be the same as the current leaving that point
2. Series resistors, voltage divider- same current, voltage depends on the resistance
3. the total voltage drop across the two resistors (i.e., from point A to point B) is the same as the voltage across the terminals of the power supply
4. the current entering any particular point must be the same as the current leaving that point. As a result of this principle, the current through resistor R1 must be the same as the current through resistor R2. We'll call this current I.
5. Vmiddle; The diagram below replaces points A and B with the corresponding voltages at those points (relative to ground). We've also added an unknown voltage Vm (m for middle) to represent the voltage on the wire connecting the two resistors
6. voltage divider, Vm; because the voltage across the second resistor is less than the power-supply voltage









**Capacitor Circuits**

-Resistor networks are fairly "static," meaning their parameters don't change much over time, like for a light bulb

-Capacitor to create a voltage drop that increases or decreases over time

-charge can move in a conductor, and it is moved by the electric force; Generally, wires are electrically neutral, but they can conduct charge, and charge can also build up in portions of the material in response to electric forces

-Capacitor, a device involving conducting plates, whatever their shape; Charge will accumulate until the voltage drop between the two plates is equivalent to the supply voltage, V. Note that the existence of an electric force between the plates (and thus an electric potential difference) is clearly seen because one plate is positively charged and the other is negatively charged. In essence, these plates are like a power supply that is "charged" or "energized" by the battery (or other supply) in the circuit

-larger plates leave more room for charge to accumulate. Furthermore, the closer the plates, the stronger the force between accumulating charge

-The ability of a capacitor to hold charge is called its capacitance, which we'll denote as C. (The SI unit of capacitance is the farad --we won't deal with this unit much, though. Nevertheless, one farad is equal to one coulomb per volt

-Q = CV, where Q is the charge stored in the capacitor, C is the capacitance, and V is the voltage

-as the excess charge in the top plate of the capacitor flows to ground, the capacitor loses its stored energy, meaning its voltage decreases. Thus, according to Ohm's law, the current decreases as well. This process continues until the charge on the capacitor is depleted; at this point, the circuit is "dead" (meaning simply that there is no more voltage across or current through R and C). (Incidentally, the positive charge in this case may best be seen as traveling to the lower plate of the capacitor, where it "neutralizes" the negative current that accumulated when the capacitor was charged

-capacitors are electronic components that can store electrical energy by storing charge, as in radio communication circuits

**Fundamentals of Magnetism**

-Magnetism, Inductors and Transformers

-gravitational force, electric force, magnetic force

-magnetism has its source in electric charge

-magnetic field and magnetic force

-induction, this creation of charge as a result of a changing magnetic field through a wire loop, how electricity is generated (a "wire loop" is moved in a magnetic field, creating a current that supplies homes, businesses, and so on)

-a changing magnetic field (increasing, in this case) creates a current--which could be troublesome if the current induced by the magnetic field is in the same direction as the current created by the power supply, as this would create a "chain reaction" leading to infinite current through the loop! As it turns out, the current induced by the changing magnetic field in this case is opposite that generated by the voltage supply. This induced current will "cancel" part of the generated (by the power supply) current until the current through the circuit reaches



-current creates a magnetic field; a loop of wire creates a magnetic field when a current flows through it, and a current can be induced in it when the magnetic field through the loop changes (increases or decreases)

-the current through a loop is "opposed" by a reverse current because of the changing magnetic field

**Inductor Circuits**

-Inductors are important to communications circuits as well as transformers

-inductor; a length of wire and coil it up like a spool of thread

-a spool of thread: that, in essence, is an inductor. Note that an inductor is still a conducting path--it has no resistance (if we assume that it is made with a perfect conductor), and current can flow through it, unlike in a capacitor. Because the inductor has multiple loops, it produces a larger magnetic field for a given current than does a single loop

-An inductor is like a capacitor in that it stores energy--in this case, the inductor stores the energy in the form of the magnetic field (rather than by accumulating charge in the case of the capacitor, which effectively stores energy in the form of the electric force or field)

-Just as a capacitor is measured by its capacitance, an inductor is measured by its inductance, which has units of henrys (represented by the symbol H--we won't delve into what exactly a henry is, but suffice it to say it's a level of magnetic field produced by the inductor per ampere of current)

-the inductor will respond by effectively converting the kinetic energy of the current into magnetic energy

-the inductor is similar to the capacitor in that it stores energy that it can release as though it was a power supply--albeit one whose supply voltage decreases over time

**Semiconductor Devices**

-semiconductors; diodes and transistors

-a diode is a semiconductor device that does not permit current flow when the voltage drop across it is below a certain threshold

-diodes serve a variety of purposes, such as protecting circuit components that are sensitive to voltage spikes or other power events

-BJT, Bipolar Junction Transistor, 3 terminals, base, collector, emitter; uses switches, This effect is critical for computers and similar electronic devices, which use binary (ones and zeros, or "on" and "off" states) to perform their tasks. Thus, the voltage at the base controls the resistance from the collector to the emitter, which also allows transistors to be used to amplify electrical signals

-Semiconductor chips containing a number of interconnected transistors and other silicon devices are called integrated circuits

-Electrical often applies to devices (or circuits containing devices) like resistors and capacitors, whose characteristics are fixed; electronic often applies to devices (or circuits containing devices) like transistors and diodes, whose characteristics (like resistance) can change according to applied voltages and currents.

**Electronics Applied: Transformers**

-electrical transformer near your place of residence: they're utility boxes that convert higher-voltage electricity from your utility company to a lower voltage fit for use in your house (220 volts in America)

-Direct current (DC) is electricity that has a constant supply voltage (or constant supply current) at all times (assuming no change to the circuit). A battery, for instance, provides direct current electricity: the voltage across the battery's terminals is always constant, at least as long as it still has plenty of remaining stored energy

-Alternating current (AC), on the other hand, changes over time. Typically, an AC voltage source is a sinusoidal wave, as the graph below illustrates. The rate at which the voltage changes in this case is called the frequency. The closest example of an AC power source is the power provided by your utility company. The outlets that you plug your computer, television, and other devices into are generally 110V AC outlets with a frequency of 60Hz. (The frequency is determined by the equipment used to generate the electricity.)

-transformer is a device that converts one voltage to another--either higher or lower.

1. an inductor is a device that converts electrical energy to magnetic field energy
2. a changing magnetic field from an inductor (which results from a changing current) can produce a current in another circuit when that changing magnetic field "passes through" the other circuit

-For a given current, an inductor produces a magnetic field proportional to the number of loops of wire in the inductor. Similarly, when a changing magnetic field "passes through" the inductor, the current generated is greater when the inductor has more loops than when it has fewer loops. Transformers use these basic magnetic principles to convert from one voltage to another. A transformer simply places two inductors in close proximity, with the inductors designed to produce a certain "output" voltage level relative to the "input" voltage level

1. Supply voltage; Because the supply voltage is alternating (changing), the magnetic field produced by the inductor on the with more loops changes; more loops means greater than the supply voltage
2. Magnetic field; because that magnetic field is alternating (and because it "links" to the second inductor), the voltage (or current) produced in the second inductor also changes (at the same frequency); less loops means that the inductor "receives" less of the energy in the magnetic field, meaning that the voltage across that inductor is lower than the supply voltage

-loaded, when there is a resistor or other device on the other side

-the transformer is not a power source; as a result, the inductor on the left has the same power (the product of the voltage and current) as the inductor on the right. All that happens in a transformer is that the voltage and current values are changed--the power remains the same

***A Note on Transformer Inefficiency***

Ideally, all the magnetic field in a transformer would pass through the loops of the inductors. This is not the case, however--some is outside the inductors, and that field energy is not transferred through the transformer. Thus, transformers are not perfectly (i.e., 100%) efficient. Some measures can be taken to improve efficiency, but inevitably some of the power supplied by the source is "lost" in the voltage conversion process. It's easiest, however, to assume for the sake of simplicity that transformers are perfectly efficient.

-A transformer places two inductors in close proximity, with the inductors designed to produce a certain "output" voltage level relative to the "input" voltage level. The output voltage is equal to the ratio of the number of turns on the primary and secondary coils times the input voltage. The ratio of primary and secondary voltage is the same as the ratio of primary and secondary coils.

-The power remains the same in a transformer, as a transformer is not a power source. The two inductors have the same power, the product of the voltage and current, with just the voltage and current values being changed.

**Transformers, AC Voltage**

1. A voltage causes electrons to flow
2. A flow of electrons is called current
3. Current flow generates a magnetic field (electromagnetism)
4. Looping a wire increases the magnetic field strength (coils)
5. Magnetic fields pass easily through iron
6. A changing magnetic field induces a current in a conductor
7. Transformers use alternating currents

**Transformers; AC Devices**

-mutual induction, 2 inductors placed side by side, connect 1 side to a power source, primary winding, and 1 side to a lode, secondary winding

1. Ampere’s Law; as current flows through a coil, it generates a magnetic field
2. Faraday’s Law of Induction; a changing magnetic flux leads to a voltage
3. Magnetic flux; magnetic field, B field, divided by area

**2 Transformer Models**

1. Linear Transformer Model; used primarily for communications applications, uses impedances for analysis
2. Ideal Transformer Model; used primarily for power transfer, uses voltages and number of coil turns

-transformers allow a change from one voltage to another voltage

-high-voltage low current power transmission allows long-distance power distribution systems, to low-voltage and high current

**Electronics Applied: Basic Communication Circuits**

-inductors, wireless devices, In effect, each inductor acts as an antenna, which transmits and/or receives an electromagnetic signal.

-a capacitor stores energy by "gathering" charge (effectively, it is storing energy in the electric field). It can discharge this energy by creating a current from one plate to another. An inductor, on the other hand, stores energy in the magnetic field when current flows through it. The inductor "discharges" when the current falls

***Capacitor and Inductor in a Circuit Together***

1. Assume the capacitor is charged; it will begin to discharge by sending a current through the inductor.
2. But the inductor converts some of this current to magnetic field energy. The capacitor will continue to supply current until it is discharged, but once this happens, the inductor will convert its magnetic field back into current, effectively recharging the capacitor, but in reverse relative to its original charge
3. Eventually, the magnetic field is depleted, but the capacitor has been recharged!
4. The process then repeats, but this time in the opposite direction. The frequency (number of "cycles" per second) for this process is determined by the capacitance of the capacitor and the inductance of the inductor. In effect, this process is an electrical equivalent of a spring: energy simply is passed back and forth between the magnetic field (the inductor) and the electric field (the capacitor). Because all of these components, in reality, have some resistance, eventually the process will come to a halt when all the energy is converted to heat (i.e., it is dissipated by the resistance of the components, including the wires)
5. This phenomenon can be used to "tune" a circuit to a particular carrier wave; connected to an antenna
6. This circuit will "pick out" the portion of the antenna signal at the frequency of the circuit described above and will reduce all other signal frequencies. When the inductance and capacitance are chosen correctly, the circuit would then be tuned for a particular radio station frequency, for instance
7. The signal must then be amplified and "cleaned up" before it is sent to a speaker, which converts the electrical signal to sound
8. using the ability to transmit signals using electromagnetic waves, we can use electronics to pick a particular signal out of many competing signals at different frequencies.

**Real Power and Reactive Power**

-only real power is being transferred to heat/light/etc.

-reactive power causes increased current, so more power is consumed by resistive transmission lines

-private customers generally only charged for real power, industrial customers charged for both

-alot of inductive loads in the big motors at industrial facilities

-big industrial facilities want to reduce reactive power costs

-purely reactive power uses no power

-may also want to correct for line impedance

-adding the capacitor changes the voltage and so also the power behavior of the system

-using capacitors is a common practice in heavy industry to limit reactive power

**Power Systems in the USA, Evolution and Practicality**

1. Power Systems: Generation, Transmission, and Distribution
2. NFPA Fire Code and Building Codes, Fire Safety with Construction Sites
3. Power Systems, Efficiency and Effectiveness in Power Supplies
4. Electric Railway Networks: Coal, Diesel, and Electric for Locomotives
5. Deregulation and Liberalization of Transmission and Distribution Lines
6. Insulation Breakdown in Transmission Lines, Field Theory, Electromagnetism
7. Utility Profit Margin in DIfferent Electric Generator Sources, Clean v. Transportable
8. American Capacity Market Importance, California CAISO and Texas ERCOT

When discussing power systems, and the generation, transmission, and distribution of electrical power, one of the first themes which comes to mind is that of cost effectiveness and efficiency. Are we generating the most power possible at the lowest possible cost per kilowatt hour? Is the type of power being used the most cost effective for the region, i.e., for the type of fuel supplied by the region? For example, if coal is abundant in one region, then coal power may still be more cost effective than nuclear power. Then we must factor costs such as transport costs for coal powered generators, and disposal costs for nuclear powered stations.

Evolution and practicality, we have come a long way in the history and development of our power supply systems in America, and around the world, and as this author is American, the focus of this doctoral thesis in electrical engineering is on power systems evolution and practicality in the USA, primarily, with limited scope review of global power systems technology as it relates to the general evolution and practicality of our one shared planet. In other words, there is usually only one best option at work, and one best way forward together, so whatever power systems technology is best suited for the United States of America should be of similar stature to that in other nations around the globe too.

Other topics of importance discussed in this paper include that of electric railway networks and electric locomotives and the differences and virtues between electric, diesel, or steam-driven locomotives. Second, the importance of stringent construction codes from the NFPA, National Fire Protection Association, when considering building codes at construction sites for power systems technology. Three, the deregulation and liberalization of transmission and lines that occurred in the 1990s, when governments around the world began liberalizing the regulation of the electricity market, leading to the separation of the electricity transmission business from the distribution business, as historically, transmission and distribution lines were often owned by the same company. Four, the study of insulation breakdown in transmission lines via field theory, or electromagnetism.

**Evolution of Power Systems in the USA (Wikipedia)**

Electricity is the necessary precursor to building a power station to generate, transmit, and distribute the electricity, and by the same virtue, the power station needs the element of electricity to function as well. So of course famously Nicholas Tesla (AC, Alternating Current) and Thomas Edison (DC, Direct Current) both pioneered the creation of electricity in America and around the world, both men around 1882. A year prior in 1881 the world’s first power station was built at Godalming in England, which used alternating current. The station employed two waterwheels to produce an alternating current that was used to supply seven Siemens arc lamps at 250 volts and thirty-four incandescent lamps at 40 volts.

The field of electricity had been gaining ground since the 17th century, and in 1831, Michael Faraday discovered electromagnetic induction, which helps explain how generators and transformers work. The basic principle of electromagnetic induction is that a change in magnetic flux induces an electromotive force in a loop of wire.

My purpose in describing the evolution of power systems technology in the United States is not to list the accomplishments of each man, or each individual power plant which was built, rather it is to discuss the change from fuel forms, from coal, to natural gas, to nuclear power. We have witnessed a change in our society over the last 100 years, from coal and natural gas plants to the advent of the nuclear age, and nuclear powered plants. So on one hand we have the factual discussion of the change from coal and natural gas to nuclear powered systems, and even water and wind based systems, such as, how many of each, when and where. And secondly, we have the discussion of the practicality of each type of power system, from coal, to natural gas, to nuclear, to wind, to water.

**Practicality of Power Systems in the USA**

This is where I make my case for one fuel source over another, and my underlying argument rests on coal or natural gas v. nuclear powered. I do not think that solar or wind or water powered plants are economically or electrically feasible, and my reason is that they are not powerful enough to make sense. Water, solar, and wind turbines and power plants simply cannot create enough power the way that a fossil fuel can, or nuclear power; the things that we mine out of the Earth, coal, natural gas, and nuclear fuels are vastly more chemically powerful and economically feasible than wind, water, or solar as forms of power.

And, it cannot be discounted, the impacts of fossil fuels on climate change and global warming, which I think is a very real phenomenon. I think that we should strive to reduce our carbon fuels intake, though it would be naive for example to think that electric cars make much sense, as it takes too long to charge a battery. Petroleum is the only viable option for vehicles, including automobiles and planes, and it would take too long to charge a battery between stops. Maybe this is where an argument for electric locomotives can be had, as if we have electric locomotives, then why not electric cars and electric airplanes too? It just seems easier, and more economically feasible, to fill up with petroleum or liquified natural gas, than to spend hours recharging a battery.

**Power System Protection**

Power system protection refers to the issues that may arise with the failure of an electrical power system, and proscribed methods for detecting and mitigating any failures.

In power systems protection, to protect the electrical power system from faults, you must disconnect the faulted electrical components from the rest of the electrical network, using protection devices to protect the power systems from the faults in the electrical network, with the objective naturally being to keep the power system stable and intact and fully operational as possible, by isolating only the necessary faulted components for removal and repair.

**NFPA Fire Code and Building Codes, Fire Safety with Construction Sites**

The NFPA Fact Sheet for Construction Site Fire Safety, NFPA Fact Sheet discusses ‘Risk Factors for Buildings Under Construction.’

-complying with NFPA 241 helps you manage and mitigate risks that can lead to catastrophic and costly events at construction sites

-from a carelessly disposed cigarette to failure to properly store or dispose of combustible materials, these fires often result from lack of awareness and understanding of fire risks and consequences, and they are almost always preventable

A power engineer may coordinate with other disciplines such as civil and mechanical engineers, environmental experts, and legal and financial personnel. Major power system projects such as a large generating station may require scores of design professionals in addition to the power system engineers. At most levels of professional power system engineering practice, the engineer will require as much in the way of administrative and organizational skills as electrical engineering knowledge.

**Power Systems, Efficiency and Effectiveness in Power Supplies**

**Common Phrases Used to Describe Power Systems**

1. Power engineering
2. Power systems engineering
3. Power systems technology
4. Electrical power supply systems
5. Electrical power systems
6. Electrical power engineering

**Electrical Power Supply Systems**

1. Generation Unit, Electricity Generation
2. Electrical substations to step voltage up or down
3. Transmission Unit
4. Distribution Units
5. Utilization of Power
6. Electrical Apparatus connected to such systems
7. Power plants which generate electric power
8. Transformers which raise or lower the voltages as needed
9. Transmission lines to carry power
10. Substations at which the voltage is stepped down for carrying power over the distribution lines
11. Distribution lines
12. Distribution transformers which lower the voltage to the level needed for the consumer equipment.

**Disconnectors**

Each of these power supply units consists of high voltage equipment, such as disconnectors; a disconnector, disconnect switch or isolator switch is an electrical component that is used to ensure that an electrical circuit is completely de-energized for service or maintenance. A disconnector switch is used only for breaking the circuit, and is usually not intended for normal control of the circuit, but only for safety isolation, and can be manual or motor operated. They may be paired with an earthing switch to ground the portion that has been isolated from the system for ensuring the safety of equipment and the personnel working on it, and are often found in electrical distribution and industrial applications, where machinery must have its source of driving power removed for adjustment or repair.

Electrical substations use high-voltage isolation switches to allow isolation of apparatus such as circuit breakers, transformers, and transmission lines, for maintenance. And unlike load switches and circuit breakers, disconnectors lack a mechanism for suppression of electric arcs, which occurs when conductors carrying high currents are electrically interrupted. Thus, disconnectors are off-load devices, with very low breaking capacity, intended to be opened only after the current has been interrupted by some other control device. Safety regulations of the utility must prevent any attempt to open the disconnector while it supplies a circuit. Standards for safety may also require either local motor isolators or lockable overloads, which can be padlocked.

IEC standard 62271-102 defines the functionality and features of a disconnector. Disconnectors have provisions for a lockout-tagout so that inadvertent operation is not possible. In high-voltage or complex systems, these locks may be part of a trapped-key interlock system to ensure proper sequence of operation. In some designs, the isolator switch has the additional ability to earth the isolated circuit thereby providing additional safety. Such an arrangement would apply to circuits that interconnect power distribution systems where both ends of the circuit need to be isolated.

**Power Systems Technology, Field Research Subtopics**

1. Three-phase AC power, the standard for large-scale power transmission and distribution across the modern world
2. Conversion between AC and DC power
3. Development of specialized power systems such as those used in aircraft or for electric railway networks

**Demand Cycle Generated Production for Electric Power Plants**

The production and transmission of electricity is relatively efficient and inexpensive, although unlike other forms of energy, electricity is not easily stored, and thus, must be produced based on the demand. Once in the transmission system, electricity from each generating station is combined with electricity produced elsewhere, electricity is consumed as soon as it is produced, and is transmitted at a very high speed, close to the speed of light.

**Three-phase electric power (Wikipedia)**

Three-phase electric power is a type of polyphase system in which alternating current is used for electric power generation, transmission, and distribution. It is the most common method used by electrical grids worldwide to transfer power, and is also used to power large motors and other heavy loads. A three-wire three-phase circuit is usually more economical than an equivalent two-wire single-phase circuit at the same line to ground voltage because it uses less conductor material to transmit a given amount of electrical power.

**Polyphase power systems**

A polyphase system is a means of distributing alternating-current (AC) electrical power where the power transfer is constant during each electrical cycle. AC phase refers to the phase offset value (in degrees) between AC in multiple conducting wires; phases may also refer to the corresponding terminals and conductors, as in color codes. Polyphase systems have three or more energized electrical conductors carrying alternating currents with a defined phase between the voltage waves in each conductor; for three-phase voltage, the phase angle is 120° or 2π/3 radians (although early systems used 4 wire two-phase).[[1]](#footnote-0)

Polyphase systems are particularly useful for transmitting power to electric motors which rely on alternating current to rotate. The most common example is the three-phase power system used for industrial applications and for power transmission. Compared to a single-phase, two-wire system, a three-phase three-wire system transmits three times as much power for the same conductor size and voltage. Systems with more than three phases are often used for rectifier and power conversion systems, and have been studied for power transmission.

**Electrical Grids, Power Grids**

An electrical grid is an interconnected network for electricity delivery from producers to consumers, and electrical grids vary in size and can cover whole countries or continents. In a country, the combined transmission and distribution network that is part of electricity delivery is known as the Power Grid or the National Grid. It consists of:

1. Generation, Power Stations: often located near energy and away from heavily populated areas
2. Electrical substations to step voltage up or down
3. Transmission, Electric power transmission to carry power long distances
4. Distribution, Electric power distribution to individual customers, where voltage is stepped down again to the required service voltage(s).

Although electrical grids are widespread, as of 2016, 1.4 billion people worldwide were not connected to an electricity grid.[[2]](#footnote-1) As electrification increases, the number of people with access to grid electricity is growing. About 840 million people (mostly in Africa) had no access to grid electricity in 2017, down from 1.2 billion in 2010.[[3]](#footnote-2) Electric grids need both kinds of security, physical maintenance and cyber security, as they can be prone to physical attacks and cyber hacks, including concerns relating to the more complex computer systems needed to manage grids.

In order to allow the transmission of AC power throughout the area, electric grids are nearly always synchronous, meaning all distribution areas operate with three phase alternating current (AC) frequencies synchronized. Synchronized means that voltage swings occur at almost the same time. Synchronous electric grids also enables the connecting of a large number of electricity generators and consumers, and potentially enabling more efficient electricity markets and redundant generation.

There are also systems that do not connect to the grid, which are called off-grid power systems. Reasons an off-grid power system may be used include: A) in remote locations it may be cheaper for a mine to generate its own power rather than pay for connection to the grid B) and in most mobile applications connection to the grid is simply not practical.

**Transformers**

Transformers are passive components that transfer electrical energy from one electrical circuit to another circuit, with passive elements meaning that they do not require a power supply, and active elements do require a power supply. As electrical energy can be transferred between separate coils without a metallic (conductive) connection between the two circuits, the way that a transformer works is that a varying current in any one coil of the transformer produces a varying magnetic flux in the transformer's core, which induces a varying electromotive force across any other coils wound around the same core. Faraday's law of induction, discovered in 1831, describes the induced voltage effect in any coil due to a changing magnetic flux encircled by the coil.[[4]](#footnote-3)

Transformers work in four ways, step-up, step-down, coupling, and isolation. One, for increasing low AC voltages at high current (a step-up transformer); two, for decreasing high AC voltages at low current (a step-down transformer) in electric power applications; three, for coupling the stages of signal-processing circuits; four, for isolation, where the voltage in equals the voltage out, with separate coils not electrically bonded to one another.

Since the invention of the first constant-potential transformer in 1885, transformers have become essential for the transmission, distribution, and utilization of alternating current electric power.[[5]](#footnote-4) Transformers have a wide range of designs and sizes in electronic and electric power applications, ranging in size from RF transformers less than a cubic centimeter in volume, to units weighing hundreds of tons used to interconnect the power grid.

**Electric Generators**

To generate electricity, a generator is used, which is a device that converts motive power, mechanical energy, into electrical power for use in an external circuit. In order to power a generator, which are needed to provide the power for electric power grids, we need mechanical energy, and sources of mechanical energy include steam turbines, gas turbines, water turbines, internal combustion engines, wind turbines and hand cranks. The first electromagnetic generator, the Faraday disk, was invented in 1831 by British scientist Michael Faraday.

Closely related to the electric generator is the electric motor, with the electric motor being used to induce the reverse conversion of electrical energy into mechanical energy. Many motors can even be mechanically driven to generate electricity, and frequently they make acceptable manual generators.

**Electric Motors**

An electric motor is an electrical machine that converts electrical energy into mechanical energy, and most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft. Electric motors can be powered by direct current (DC) sources, such as from batteries, or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators. An electric generator is mechanically identical to an electric motor, but operates with a reversed flow of power, converting mechanical energy into electrical energy.

Ways to classify electric motors include: power source type, internal construction, application and type of motion output. In addition to AC versus DC types, motors may be brushed or brushless, may be of various phase (see single-phase, two-phase, or three-phase), and may be either air-cooled or liquid-cooled. General-purpose motors with standard dimensions and characteristics provide convenient mechanical power for industrial use. The largest electric motors are used for ship propulsion, pipeline compression and pumped-storage applications with ratings reaching 100 megawatts. Common places that electric motors are found are in industrial fans, blowers and pumps, machine tools, household appliances, power tools and disk drives, and small motors may also be found in electric watches. Electric motors can be used in regenerative braking with traction motors, such as with electric railways for electric locomotives, where they are used in reverse as generators to recover energy that might otherwise be lost as heat and friction.

Electric motors work by propelling some external mechanism such as a fan or en elevator though producing linear or rotary force (torque), and an electric motor is generally designed for continuous rotation, or for linear movement over a significant distance compared to its size. A different option to electric motors are magnetic solenoids, which are also transducers that convert electrical power to mechanical motion, though can produce motion over only a limited distance.

Generally speaking, electric motors are more efficient than the other prime mover used in industry and transportation, the internal combustion engine (ICE), as electric motors are typically over 95% efficient while ICEs are well below 50%. Some of the advantages of electric motors include that they are also lightweight, physically smaller, are mechanically simpler and cheaper to build, can provide instant and consistent torque at any speed, can run on electricity generated by renewable sources and do not exhaust carbon into the atmosphere. Electric motors have started replacing internal combustion engines in transportation and industry, though their use in vehicles is currently limited by the high cost and weight of batteries that can give sufficient range between charges.

**Power Electronics**

Power electronics can be described as the application of solid-state electronics to the control and conversion of electric power. The first high power electronic devices were made using mercury-arc valves, though, in modern systems, the conversion is performed with semiconductor switching devices such as diodes, thyristors, and power transistors such as the power MOSFET and IGBT. In contrast to electronic systems concerned with transmission and processing of signals and data, in power electronics substantial amounts of electrical energy are processed. An AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices, such as television sets, personal computers, and battery chargers, and the power range is typically from tens of watts to several hundred watts. In industry, a common application is the variable speed drive (VSD) that is used to control an induction motor, and the power range of VSDs start from a few hundred watts and end at tens of megawatts.

The power conversion systems can be classified according to the type of the input and output power

1. AC to DC (rectifier)
2. DC to AC (inverter)
3. DC to DC (DC-to-DC converter)
4. AC to AC (AC-to-AC converter)

**Steam Turbines**

A steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft, and was invented by Charles Parsons in 1884.[[6]](#footnote-5)

A steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency from the use of multiple stages in the expansion of the steam, which results in a closer approach to the ideal reversible expansion process, and because the turbine generates rotary motion, it is best suited to be used to drive an electrical generator. About 85% of all electricity generation in the United States in the year 2014 was by use of steam turbines, and a steam turbine connected to an electric generator is called a turbo generator.[[7]](#footnote-6)

**Gas Turbines**

A gas turbine, also called a combustion turbine, is a type of continuous and internal combustion engine. The main elements common to all gas turbine engines are:

1. an upstream rotating gas compressor
2. a combustor
3. a downstream turbine on the same shaft as the compressor

A fourth component is often used to increase efficiency (on turboprops and turbofans), to convert power into mechanical or electric form (on turboshafts and electric generators), or to achieve greater thrust-to-weight ratio (on afterburning engines).

A gas turbine operates with a Brayton cycle with air as the working fluid: atmospheric air flows through the compressor that brings it to higher pressure; energy is then added by spraying fuel into the air and igniting it so that the combustion generates a high-temperature flow; this high-temperature pressurized gas enters a turbine, producing a shaft work output in the process, used to drive the compressor; the unused energy comes out in the exhaust gases that can be repurposed for external work, such as directly producing thrust in a turbojet engine, or rotating a second, independent turbine (known as a power turbine) that can be connected to a fan, propeller, or electrical generator. The purpose of the gas turbine determines the design so that the most desirable split of energy between the thrust and the shaft work is achieved. The fourth step of the Brayton cycle (cooling of the working fluid) is omitted, as gas turbines are open systems that do not reuse the same air.

Gas turbines are used to power aircraft, trains, ships, electrical generators, pumps, gas compressors, and tanks.[[8]](#footnote-7)

**Water Turbines**

A water turbine is a rotary machine that converts kinetic energy and potential energy of water into mechanical work. Water turbines were developed in the 19th century and were widely used for industrial power prior to electrical grids, though now they are mostly used for electric power generation. Water turbines are mostly found in dams to generate electric power from water potential energy.

**Internal Combustion Engines**

An internal combustion engine (ICE) is a heat engine in which the combustion of a fuel occurs with an oxidizer, usually air, in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is applied usually to pistons, turbine blades, a rotor, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful work. The internal combustion engine replaced the external combustion engine for applications where weight or size of the engine is important.

The first commercially successful internal combustion engine was created by Étienne Lenoir around 1860 and the first modern internal combustion engine was created in 1876 by Nicolaus Otto (see Otto engine).[[9]](#footnote-8)

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four-stroke and two-stroke piston engines, along with variants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described. Firearms are also a form of internal combustion engine, though of a type so specialized that they are commonly treated as a separate category.[[10]](#footnote-9)

In contrast, in external combustion engines, such as steam or Stirling engines, energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids for external combustion engines include air, hot water, pressurized water or even liquid sodium, heated in a boiler.

ICEs are usually powered by energy-dense fuels such as gasoline or diesel fuel, liquids derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for vehicles such as cars, aircraft and boats.

ICEs are typically powered by fossil fuels like natural gas or petroleum products such as gasoline, diesel fuel or fuel oil. Renewable fuels like biodiesel are used in compression ignition (CI) engines and bioethanol or ETBE (ethyl tert-butyl ether) produced from bioethanol in spark ignition (SI) engines. Renewable fuels are commonly blended with fossil fuels. Hydrogen, which is rarely used, can be obtained from either fossil fuels or renewable energy.

**Wind Turbines**

A wind turbine is a device that converts the wind's kinetic energy into electrical energy. Wind turbines are manufactured in a wide range of sizes, with either horizontal or vertical axes. It is estimated that hundreds of thousands of large turbines, in installations known as wind farms, now generate over 650 gigawatts of power, with 60 GW added each year.[[11]](#footnote-10) They are an increasingly important source of intermittent renewable energy, and are used in many countries to lower energy costs and reduce reliance on fossil fuels. One study claimed that, as of 2009, wind had the "lowest relative greenhouse gas emissions, the least water consumption demands and... the most favourable social impacts" compared to photovoltaic, hydro, geothermal, coal and gas.[[12]](#footnote-11)

Smaller wind turbines are used for applications such as battery charging for auxiliary power for boats or caravans, and to power traffic warning signs. Larger turbines can contribute to a domestic power supply while selling unused power back to the utility supplier via the electrical grid.

**Crank Mechanisms**

A crank is an arm attached at a right angle to a rotating shaft by which circular motion is imparted to or received from the shaft, and when combined with a connecting rod, it can be used to convert circular motion into reciprocating motion, or vice versa. The arm may be a bent portion of the shaft, or a separate arm or disk attached to it, and attached to the end of the crank by a pivot is a rod, usually called a connecting rod (conrod).

The term often refers to a human-powered crank which is used to manually turn an axle, as in a bicycle crankset or a brace and bit drill. In this case a person's arm or leg serves as the connecting rod, applying reciprocating force to the crank. There is usually a bar perpendicular to the other end of the arm, often with a freely rotatable handle or pedal attached.

**AC to DC Conversion**

-AC used in power transmission

-DC used to power electronics

-diode rectifiers are used in converting AC to DC

**DC Power Supply Components**

1. AC Source; 60 Hz, 120vAC; 120vRMS 60 Hz sine wave
2. Transformer; steps voltage up or down
3. Rectifier; introduces DC component
4. Low-pass filter capacitor; reduces AC component to smooth output
5. DC output

-larger filter capacitors which result in larger time constants result in a smoother output voltage or smaller ripple voltage

***Time Constant; τ= RC***

1. Larger time constant; slower discharge
2. Smaller time constant; faster discharge

**Generation Units, Selection, Design and Construction**

Beaty, H. and Shaalan, H. (1984) Handbook of Electric Power Calculations, McGraw Hill.

The four major parameter decisions which must be made for any new electric power generating plant or unit include: 1) choice of energy source or fuel 2) type of generation system 3) unit and plant rating, and 4) plant site. Then there are also secondary interrelated factors which must taken into account such as technical, economic, and environmental factors.

**Energy Source and Generator Type**

A question that arises when constructing new generator units is whether the unit can use different types of fuels, and this answer is generally no, although a single energy or fuel source may be used in different types of generating systems, at least conceptually in the planning phase. Once plant construction has been completed however, conversion from fuel to another will entail significant capital costs and operational difficulties. For example, steam cycles, combined steam and gas turbines, and fuel cells all allow for potentially the same energy source. Combined steam and gas turbines are systems where the hot exhaust gases are delivered to a heat-recovery steam generator to produce steam that is used to drive a steam turbine. Fuel cells are systems having cathode and anode electrodes separated by a conducting electrolyte that converts liquid or gaseous fuels to electric energy without the efficiency limits of the Carnot Cycle.

The three main classes of energy sources or fuels include: 1) fossil fuels such as coal, oil or natural gas 2) nuclear fuels such as uranium or thorium 3) renewables such as wind, water (hydroelectric), geothermal steam, and solar (photovoltaic). Common generation systems include: 1) steam cycle systems (steam-turbines, with or without cogeneration team for district heating and industrial steam loads) 2) hydroelectric systems 3) combustion-turbine systems (gas turbines) 3) combined cycle systems (combined steam and gas turbine) 4) internal-combustion engines (diesel).

**Unit and Plant Ratings**

1. Capable of serving the current expected maximum electrical load and providing some spinning reserve for reliability and future load growth considerations
2. Capable of serving only the expected maximum electrical load; peaking unit
3. Capable of serving most of the expected maximum load; using conservation or load management to eliminate the load that exceeds generation capacity

**Plant Site**

1. Near electrical load
2. Near fuel source
3. Near water source (water availability)
4. Near existing electrical transmission system
5. Near existing transportation system
6. Near or on existing electrical-generation plant site

There is often no one type of fuel source that is best based on the available criteria. For example, when comparing coal and nuclear energy, coal has higher fuel costs though lower capital costs. Economic choice is therefore often dependent on the expected capacity factor for the unit, or equivalent full-load hours of operation expected per year.

Environmental aspects often involve subjective decision making about the expected environmental impacts of the fuel source and generation type. For example, coal and nuclear energy both have significant though different environmental impacts. And hydroelectric power, although clean and renewable, involves the construction of dams, which may affect aquatic life or flood land that is currently used for farming or habitation.

**Plant, Unit Rating, and Site**

The choice of plant, unit rating, and site is an interrelated process. This includes proximity to and availability of water, proximity of fuel or fuel transportation, and soil characteristics. For example, for plants with capacity unit ratings above 100 MW, combustion turbine, diesel, or geothermal units could not be used unless multiple units were installed. The available plant site can also have an impact on the choice of fuel, power-generating system, and plant rating, including the need for cooling water or fossil fuels. For a typical 1000-MW unit, fossil-fuel or nuclear-energy steam-cycle units require copious amount of cooling water, from 50.5 to 63.1 /s, or 800,000 to 1,000,000 gal/min, whereas gas turbines require essentially no cooling water. For units rated at 1000 MW, coal fired plants require over 2.7 million tonnes or 3 million tons of coal annually, whereas nuclear units rated at 1000 MW require only 32.9 tonnes or 36.2 tons of enriched uranium dioxide, annually. As far as disposal costs, coal-fired plants require disposal of large quantities of ash and scrubber sludge, whereas natural gas-fired units require no solid waste disposal.

**Alternatives**

Most electric-power generating systems are available in a variety of ratings, though installed capital costs (on a dollars per kilowatt basis) and system efficiencies (heat rates) are different for each rating. Each generating system is also available in many variations of equipment types, equipment configurations, system parameters, and operating conditions.

For example, there are both pulverized-coal and cyclone boilers that are of either the drum or once-through type. Steam turbines used in steam cycles can be of either the tandem-compound or cross-compound type, with any number of feedwater heaters, and be either of the condensing, back-pressure, or extraction (generation) type. There are also a number of standard inlet and reheat system conditions (i.e., temperature and pressures). Units may also be designed for base-load, intermediate-load, cycling, or peaking operation. Each combination of equipment type, equipment configuration, system parameters, and operating conditions must be evaluated based on its own advantages and disadvantages (Beaty and Shaalan, 1984).

**Electrical Load**

The electrical load on any electric-power generator system generally fluctuates on a daily basis, and on an annual basis, will fluctuate between a minimum load level, below which electrical demand never falls, and a maximum or peak, which occurs only for a few hours per year. The load duration curves suggests that the load be above 70% of the peak about 40% of the year, and the minimum load, the laid exceeded 100% of the time, is 33% of the peak value.

For U.S. utility systems the minimum annual load is 27 to 33 percent of the peak annual load. The load level exceeds 90% of the peak value 1 to 5 percent of the time, exceeds 80% of the peak value 5 to 30 percent of the time, and exceeds 33 to 45 percent of the peak 95 percent of the time. Annual load factors [(average load/peak annual load) x 100%] range from 55 to 65 percent.

Even though the frequency of a system fluctuates as the load varies, the turbine governors always bring it back to 60 Hertz. The system gains or loses a few cycles throughout the day due to these fluctuations, though when the accumulated loss or gain is about 180 cycles, the error is corrected by making all the generators turn either faster or slower for a brief period of time.

A state of emergency is created by a major disturbance on a system, or a contingency, with immediate steps being taken to prevent the contingency from spreading to other regions. A major contingency could be something such as the sudden loss of an important load or a permanent short-circuit on a transmission line.

When a big load is suddenly lost, all the turbines begin to speed up and the frequency increases everywhere on the system. Conversely, if a generator is disconnected, the speed of the remaining generators decreases because they suddenly have to carry the entire load. When this happens, a disconnected generator, the frequency then starts to decrease at a rate that may reach 5 Hz/s, and no time may be lost under these conditions. Therefore, load shedding, dropping some load, must occur if conventional methods are unable to bring the frequency back to normal. Such load shedding is done by frequency-sensitive relays that open selected circuit breakers as the frequency falls.

Economic savings can be achieved by using either 1) higher capital cost, lower operating cost units (such as steam-cycle units) to serve the base load, and 2) lower capital cost, higher operating cost units (such as combustion turbines) to serve the peaking portion of the load. The intermediate load range is next served by a combination of base-load, peaking, combined-cycle, and hydroelectric units that have intermediate capital and operating costs and have design provisions that reliably permit the required load fluctuations and hours per year of operation. Planning procedures and production cost vs. capital cost tradeoff evaluation methods are used to evaluate the optimal combination of base-load, intermediate-load, and peaking-load power generating units of various sizes.

**Steps to Determine the Optimum New Electric-Power Generating Unit**

1. Identify all possible energy source (fuel) and electric-generation-system combination alternatives
2. Eliminate alternatives that fail to meet system commercial-availability criteria
3. Eliminate alternatives that fail to meet energy source (fuel) commercial-availability criteria
4. Eliminate alternatives that fail to meet other functional or site-specific criteria
5. Eliminate alternatives that are always more costly than other feasible alternatives
6. Calculate the appropriate annual fixed-charge rate
7. Calculate fuel costs on a dollars per million Btu basis
8. Calculate the average net generation unit heat rates
9. Construct screening curves for each system
10. Use screening-curve results to choose the alternatives to be evaluated further
11. Construct screening curves for feasible renewable and alternative energy sources and generation systems and compare with alternatives in Step 5E
12. Determine coincident maximum predicted annual loads over the entire planning period
13. Determine the required planning reserve margin
14. Evaluate the advantages and disadvantages of smaller and larger generation-unit and plant ratings
15. Consider the economy-of-scale savings associated with larger unit and plant ratings
16. Consider the operational difficulties associated with unit ratings that are too large
17. Take into account the range of ratings commercially available for each generation-system type
18. Consider the possibility of jointly owned units
19. Consider the forecast load growth
20. Determine the largest unit and plant ratings that can be used in generation expansion plans
21. Develop alternative generation expansion plans
22. Compare generation expansion plans on a consistent basis
23. Determine the optimum generation expansion plan by using an iterative process
24. Use the optimum generation expansion plan to determine the next new generation units or plants to be installed
25. Determine the generator ratings for the new generation units to be installed
26. Determine the optimal plant design
27. Evaluate tradoff of annual operation and maintenance costs vs. installed capital costs
28. Evaluate tradeoffs of thermal efficiency vs. capital costs and/or operation and maintenance costs
29. Evaluate tradeoff of unit availability (reliability) and installed capital costs and/or operation and maintenance costs
30. Evaluate tradeoff of unit rating vs. installed capital costs

**Calculation Procedure, Optimum Electric-Power Generating Unit**

1. Identify alternatives; It is necessary to evaluate a number of installation sequences with various ratings for the various combinations of fuel and electric-power generating systems.
2. Eliminate alternatives that fail to meet system commercial availability criteria; The elimination of systems that are simply not developed to the stage where they can be considered to be available for installation on a utility system in the required time period.
3. Eliminate alternatives that fail to meet energy-source fuel commercial availability criteria; The elimination of systems that require fuels that are generally not commercially available in the required quantities.
4. Eliminate alternatives that fail to meet other functional or site-specific criteria; The elimination of alternatives which are not feasible for the existing utility power system involved, including current and future considerations. Such as: 1) wind, unless 100- to 200-kW units with a fluctuating and interruptible power output is available 2) geothermal, unless the utility is located in the geyser regions of North California 3) conventional hydroelectric, unless the utility is located in a region where elevated water is either available or can be made available by the construction of a river dam 4) tidal hydroelectric, unless the utility is located near one of the few feasible oceanic coastal basin sites. As for future considerations: 1) coal and oil, may be eliminated due to inability to meet governmental clean-air and/or disposal standards (coal) 2) oil or natural gas, fuel unavailability for a variety of reasons including government policy 3) hydroelectric, lack of a site where a dam can be constructed without excessive ecological and socioeconomic impacts 4) nuclear, inability to obtain the necessary permits and licenses for a variety of governmental and political reasons.
5. Eliminate alternatives that are always more costly than other feasible alternatives; The elimination of alternatives in this stage is based on a comparison of the total power-generating costs of the various systems, considering both the fixed costs (capital plus fixed operation and maintenance costs) and the production costs (fuel costs plus variable operation and maintenance costs). This comparison can be made with screening curves, which show the annual operation costs per installed kilowatt hour (dollars per year per kilowatt) is plotted as a function of capacity factor (or equivalent full-load operation hours per year) for each combination of fuel and electric-power generating system.

**Rates to be Calculated**

1. Annual capacity factor
2. Annual fixed-charge rate
3. Fuel costs
4. Average net heat rates
5. Construction of screening curve

**Annual Capacity Factor**

() 100 percent= 68.2 percent

**Annual Fixed-Charge Rate**

The annual fixed-charge rate represents the average or levelized annual carrying charges for return on installed capital, depreciation or return on capital, taxes, and insurance. Fixed charge rates for investor-owned utilities generally range from 15 to 20 percent, and fixed charge rates for publicly owned utilities are generally about 5 percent lower. The fixed charge rate breakdown for an investor-owned electric utility is: 1) Return on Installed Capital, 7.7% 2) Depreciation or return of the capital, 1.4% 3) Taxes, 6.5% 4) Insurance, 0.4%.

**Fuel Costs**

-on a dollars per megajoule (and million Btu) basis

1. Costs of Coal; On a dollars per megajoule basis, the cost of coal at $39.68/tonne ($36/ton) with an heating value of 27.915 MJ/kg (12,000 Btu/lb) is ($39.68/tonne/[(1000 kg/tonne)(27.915 MJ/kg)] = $0.001421/MJ = $1.50/million Btu.
2. Costs of Oil; On a dollars per megajoule basis, the cost of oil at $28 per standard 42-gal barrel ($0.17612/L) with a heating value of 43.733 MJ/kg (18,800 Btu/lb) and a specific gravity of 0.91 is ($0.17612/L)/[(43.733 MJ/kg)(0.91 kg/L)] = $0.004425/MJ = $4.67/million Btu.
3. Costs of Natural Gas; On a dollars per megajoule basis, natural gas at $0.1201/($3.40 per thousand standard cubic feet) with a heating value of 39.115 MJ/= 1050 Btu/1000 costs ($.1201/)/(39.115 MJ/) = $0.00307/MJ = $3.24/million Btu.
4. Costs of Nuclear Fuel; On a dollars per megajoule basis, nuclear fuel at $75.36/MWday costs ($75.36/MWday)/[(1.0 J/MWs)(3600 s/h)(24 h/day)] = $0.00087/MJ = $0.92/million Btu.

**Average Net Heat Rates**

1. Define the Net Heat Rate
2. Compute the Total Heat Input to Boiler
3. Compute the Net Power Output of the Generating Unit
4. Determine the Net Heat Rate of the Generating Unit

**Construction of Screening Curve**

1. Determine the Fixed Annual Capital Cost
2. Compute Fixed Operation and Maintenance Costs
3. Compute Cost per Year at a Capacity Factor of Zero
4. Determine the Fuel Cost

**Noncoincident and Coincident Maximum Predicted Annual Loads**

1. Analyze the Data in the Table
2. Compute Noncoincident Demands
3. Compute Coincident Demands

**Required Planning Reserve Margin**

1. Determine what percentage increases are adequate
2. Calculate reserve and installed capacity

**Ratings of Commercially Available Systems**

1. Consider the nuclear units
2. Consider fossil-fuel units

**Hydropower Generating Stations**

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**Largest Units and Plant Ratings Used in Generating-System Expansion Plans**

1. Select unit ratings
2. Determine the ratings for 1 percent growth per year

**Alternative Generating System Expansion Plans**

1. Compute the installed capacity in year 6
2. Compute the reserve percentage

**Generator Ratings for Installed Units**

1. Compute the Rating

**Optimum Plant Design**

1. Choose design
2. Perform economic analyses

**Annual Operation and Maintenance Costs vs. Installed Capital Costs**

1. Examine initial capital costs
2. Analyze fixed and annual costs

**Thermal Efficiency vs. Installed Capital and/or Annual Operation and Maintenance Costs**

1. Compute the annual fixed charges and fuel cost
2. Make a comparison

**Replacement of Fuel Cost**

1. Analyze the problem
2. Calculate the replacement energy cost

**Capability Penalty**

1. Analyze the problem
2. Calculate the capability penalty

**Electric Locomotives**

An electric locomotive is a locomotive powered by electricity from overhead lines, a third rail or on-board energy storage such as a battery or a supercapacitor. There are also forms of electric locomotives, such as diesel engines (diesel-electric) or gas turbines (gas turbine electric) with on-board fueled prime movers, where the electric generator/motor combination serves only as a power transmission system. Two primary advantages of electric locomotives are that they are quiet compared to diesel locomotives, since there is no engine and exhaust noise and less mechanical noise, and the lack of reciprocating parts means electric locomotives are easier on the track, thereby reducing track maintenance.

***Advantages of Electric Locomotives***

Electric locomotives reap efficiency gains from electric motors and regenerative braking. The efficiency of electric motors is often above 90%, not including the inefficiency of generating the electricity, and regenerative braking allows kinetic energy to be recovered during braking to put power back on the line, with newer electric locomotives using AC motor-inverter drive systems that provide for regenerative braking.[[13]](#footnote-12)

***Power Plants and Electric Locomotives***

Power plants that burn fossil fuels are cleaner than mobile sources such as automobiles and trains, thus making electric locomotives cleaner than their diesel counterparts. Also, since power plant capacity is far greater than any individual locomotive uses, electric locomotives can also have a higher power output than diesel locomotives and they can produce even higher short-term surge power for fast acceleration. Electric locomotives typically cost 20% less than diesel locomotives, their maintenance costs are 25-35% lower, and cost up to 50% less to run.[[14]](#footnote-13)

***Disadvantages of Electric Locomotives***

Four issues that affect the electrification of railways in the United States are: electric railways have a high cost for infrastructure, public policy and higher property taxes in the US interfere with electrification, railways are privately owned not publicly owned in the United States, and EPA regulations.

Electric railways and electrification have a high cost for infrastructure, and this infrastructure includes: overhead lines or third rail, substations, and control systems. Public policy in the US also interferes with electrification, with higher property taxes being imposed on privately owned rail facilities if they are electrified. Oftentimes when a public infrastructure is privately owned, the owners will not want to make as many investments to upgrade the service, such as the electrification railways, as it is not considered part of the national transport infrastructure, just like roads, highways and waterways, which are often financed by the state. In Europe and elsewhere, operators of the rolling stock pay fees according to rail use. This makes possible the large investments required for the technically and, in the long-term, also economically advantageous electrification. As for EPA regulations, the EPA regulates exhaust emissions on locomotive and marine engines, similar to regulations on car & freight truck emissions, in order to limit the amount of carbon monoxide, unburnt hydrocarbons, nitric oxides, and soot output from these mobile power sources.[[15]](#footnote-14)

**Railway Electrification Systems, Electric Railway Networks**

Railway electrification has constantly increased in the past decades, and as of 2012, electrified tracks account for nearly one-third of total tracks globally.[[16]](#footnote-15) An important topic to remember when discussing electric locomotives and railway electrification systems, or electric traction, is that they are two separate topics, the electric locomotive runs on the railway electrification system, though they are quite separate systems. The key attribute about a railway electrification system is that it supplies electric power to railway trains and trams without an on-board prime mover or local fuel supply. An on-board prime mover would be a diesel engine or gas turbine.

Two methods of transport used by electric railways are either 1) electric locomotives, hauling passengers or freight in separate cars, or 2) electric multiple units, passenger cars with their own motors. Like electric locomotives too, electricity is also usually generated in large and efficient generating stations, transmitted to the railway network, and distributed to the trains. Although most electric railways purchase power directly from the electric utility, an electric railway may also have their own dedicated generating stations and transmission lines. In either instance, the railway would provide its own distribution lines, switches, and transformers.

A nearly continuous conductor running along the track is used to supply power to electric railways, that usually takes one of two forms, either overhead wire or third-rail systems: 1) an overhead line, suspended from poles or towers along the track or from structure or tunnel ceilings, or 2) a third rail mounted at track level and contacted by a sliding pickup shoe. Both overhead wire and third-rail systems usually use the running rails as the return conductor, though some systems use a separate fourth rail for this purpose.

***Advantages and Disadvantages***

Compared to diesel engines, electric railways offer several advantages, including: substantially better energy efficiency, lower emissions, and lower operating costs. Electric locomotives are also usually quieter, more powerful, and more responsive and reliable than diesels. Something that is important in tunnels and urban areas is that they have no local emissions, with local meaning from the device itself, not power plant emissions. Another advantage that some electric traction systems provide is regenerative braking, which turns the train's kinetic energy back into electricity and returns it to the supply system to be used by other trains or the general utility grid. As far as fuel sources, diesel locomotives burn petroleum, though electricity can be generated from diverse sources, including renewable energy, which means that electrified railways use cleaner fuel sources.[[17]](#footnote-16) Concerns of resource independence will play a role in the decision to electrify railway lines, such as Switzerland after World War I and World War II. Switzerland has few oil or coal deposits, so they electrified their railway network using hydroelectric power.[[18]](#footnote-17)

A few disadvantages of electric traction include: high capital costs that may be uneconomic on lightly trafficked routes, a relative lack of flexibility (since electric trains need third rails or overhead wires), and a vulnerability to power interruptions. Electro-diesel locomotives and Electro-diesel multiple units reduce these problems as they are capable of running on diesel power during an outage or on non-electrified routes.

**Electric Railway Networks: Coal, Diesel, and Electric for Locomotives**

<https://www.publicpower.org/policy/wholesale-electricity-markets-and-regional-transmission-organizations>

There are seven RTOs operating in the U.S.: ISO-NE; NYISO; PJM; MISO; CAISO; SPP; and the Electric Reliability Council of Texas (ERCOT). Of the seven, only ERCOT, which operates entirely within the state of Texas, is not subject to FERC jurisdiction.

**California ISO (CAISO)**

CAISO operates only in California, but it is under FERC’s jurisdiction because the state’s transmission grid is interconnected with the rest of the West. Some public power utilities in the state have chosen not to turn over operational control of their transmission facilities to CAISO, but all public power utilities are impacted by CAISO’s energy market prices and provision of transmission service due to the web of business relationships among market participants in the state. In October 2014, the ISO began operating a voluntary energy imbalance market (EIM) with PacifiCorp, which has since been joined by a number of investor-owned and public power utilities. The EIM is generally viewed as providing many of the benefits from centralized energy dispatch over a large geographic area, but without the risks of a full RTO.

CAISO does not operate a capacity market, and in 2018, FERC rejected a complaint requesting the creation of a capacity market in CAISO. APPA and multiple other parties protested the complaint.

**ISO-New England (ISO-NE)**

ISO-NE operates in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. The region is facing numerous challenges from growing reliance on natural gas without a corresponding increase in natural gas pipeline capacity, retirements of nuclear and coal plants, and rising energy and capacity prices. ISO-NE operates a mandatory capacity market, called the forward capacity market, which procures capacity three years in advance.

**Midcontinent ISO (MISO)**

MISO operates in all or parts of Arkansas, Illinois, Indiana, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, North Dakota, South Dakota, Texas, Wisconsin, and Manitoba, Canada. MISO has seen both defections by transmission-owning utilities—First Energy and Duke left MISO to join PJM in 2011 and 2012 respectively—and a significant expansion of its territory at the end of 2013 to include what is known as MISO South. Many industry observers believe the former MISO utilities that joined PJM did so to receive lucrative capacity market payments not available from MISO, while MISO’s revisions to its capacity market were an incentive for the southern expansion. In 2012, FERC approved a voluntary locational capacity market for MISO, but ruled against mandatory participation or a minimum offer price rule in that market. MISO filed a proposal in 2016 to create a mandatory capacity auction in those regions where there is retail choice and the utilities are not responsible for supplying power to their customers, which was later rejected by FERC.

**New York ISO (NYISO)**

NYISO operates only in New York, but is FERC-jurisdictional because the state’s transmission grid is interconnected with the rest of the region. New York City is a very transmission-constrained area within NYISO, which requires substantial mitigation of the power sales into that area. The ISO operates a shorter-term capacity market than in PJM and ISO-NE, but it is only mandatory within the New York City and Lower Hudson Valley zones.

**PJM Interconnection**

PJM operates in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia. PJM operates a three-year forward mandatory capacity market, called the reliability pricing model. In 2018, FERC found that the capacity market rules in PJM are not just and reasonable because they do not prevent reductions from capacity prices due to state efforts to procure renewable resources or prevent nuclear plants from retiring. An investigation was opened by FERC into PJM’s capacity market rules.

**Southwest Power Pool**

SPP operates in all or parts of Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wyoming. SPP has approached RTO formation and market development on a slower and more conservative track than many other RTOs. SPP transitioned to a full RTO with both a day-ahead and real-time market in March 2014, but has not implemented a capacity market.

**Regional Transmission Organizations/Independent System Operators**

Independent System Operators (ISO) grew out of Orders Nos. 888/889 where the Commission suggested the concept of an Independent System Operator as one way for existing tight power pools to satisfy the requirement of providing non-discriminatory access to transmission. Subsequently, in Order No. 2000, the Commission encouraged the voluntary formation of Regional Transmission Organizations (RTO) to administer the transmission grid on a regional basis throughout North America (including Canada). Order No. 2000 delineated twelve characteristics and functions that an entity must satisfy in order to become a Regional Transmission Organization.

Traditional wholesale electricity markets exist primarily in the Southeast, Southwest and Northwest where utilities are responsible for system operations and management, and, typically, for providing power to retail consumers. Utilities in these markets are frequently vertically integrated – they own the generation, transmission and distribution systems used to serve electricity consumers. They may also include federal systems, such as the Bonneville Power Administration, the Tennessee Valley Authority and the Western Area Power Administration. Wholesale physical power trade typically occurs through bilateral transactions, and while the industry had historically traded electricity through bilateral transactions and power pool agreements, Order No. 888 promoted the concept of independent system operators (ISOs).

Along with facilitating open-access to transmission, ISOs operate the transmission system independently of, and foster competition for electricity generation among, wholesale market participants. Several groups of transmission owners formed ISOs, some from existing power pools. In Order No. 2000, the Commission encouraged utilities to join regional transmission organizations (RTOs) which, like an ISO, would operate the transmission systems and develop innovative procedures to manage transmission equitably. Each of the ISOs and RTOs have energy and ancillary services markets in which buyers and sellers could bid for or offer generation. The ISOs and RTOs use bid-based markets to determine economic dispatch. While major sections of the country operate under more traditional market structures, two-thirds of the nation’s electricity load is served in RTO regions.

**California (CAISO)**

The California Independent System Operator (CAISO) operates a competitive wholesale electricity market and manages the reliability of its transmission grid. CAISO provides open access to the transmission and performs long-term planning. In managing the grid, CAISO centrally dispatches generation and coordinates the movement of wholesale electricity in California and a portion of Nevada. CAISOs markets include energy (day-ahead and real-time), ancillary services, and congestion revenue rights. CAISO also operates an Energy Imbalance Market (EIM), which currently includes CAISO and other balancing authority areas in the western United States.

CAISO was founded in 1998 and became a fully functioning ISO in 2008. The Energy Imbalance Market launched in 2014 with PacifiCorp as the first member or EIM Entity. The EIM serves parts of Arizona, Oregon, Nevada, Washington, California, Utah, Wyoming and Idaho.

**Midcontinent (MISO)**

MISO operates the transmission system and a centrally dispatched market in portions of 15 states in the Midwest and the South, extending from Michigan and Indiana to Montana and from the Canadian border to the southern extremes of Louisiana and Mississippi. The system is operated from three control centers: Carmel, Indiana; Eagan, Minnesota; and Little Rock, Arkansas. MISO also serves as the reliability coordinator for additional systems outside of its market area, primarily to the north and northwest of the market footprint.

MISO was not a power pool before organizing as an ISO in December 2001. It began market operations in April 2005. In January 2009, MISO started operating an ancillary services market and combined its 24 separate balancing areas into a single balancing area. In 2013, the RTO began operations in the MISO South region, including the utility footprints of Entergy, Cleco, and South Mississippi Electric Power Association, among others, in parts of Arkansas, Mississippi, Louisiana, and Texas.

**New England (ISO-NE)**

As the RTO for New England, ISO-NE is responsible for operating wholesale power markets that trade electricity, capacity, transmission congestion contracts and related products, in addition to administering auctions for the sale of capacity. ISO-NE operates New England’s high-voltage transmission network and performs long-term planning for the New England system. ISO-NE serves six New England states: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. New England’s all-time peak load was 28 GW in summer 2006. ISO-NE is interconnected with the New York Independent System Operator (NYISO), TransEnergie (Québec) and the New Brunswick System Operator. ISO-NE imports around 17 percent of its annual energy needs from Québec, NYISO, and New Brunswick. In ISO-NE’s annual Forward Capacity Auction (FCA), both generator and demand resources offer capacity three years in advance of the period for which capacity will be supplied. The three-year lead time is intended to encourage participation by new resources and allow the market to adapt to resources leaving the market. ISO-NE relies primarily on natural gas-fired and nuclear generation, accounting for 49% and 31% of the systems supply in 2016, respectively.

**New York (NYISO)**

The creation of the New York Independent System Operator (NYISO) was authorized by FERC in 1998 and launched on Dec. 1, 1999. The NYISO footprint covers the entire state of New York. NYISO is responsible for operating wholesale power markets that trade electricity, capacity, transmission congestion contracts, and related products, in addition to administering auctions for the sale of capacity. NYISO operates New York’s high-voltage transmission network and performs long-term planning.

The chronic transmission constraints in NYISO are in the southeastern portion of the state, leading into New York City and Long Island. As a result of their dense populations, New York City and Long Island are the largest consumers of electricity. Consequently, energy flows from the west and the north toward these two large markets, pushing transmission facilities near their operational limits. This results in transmission constraints in several key areas, often resulting in higher prices in the New York City and Long Island markets

**Northwest**

The West includes the Northwest Power Pool (NWPP), the Rocky Mountain Power Area (RMPA) and the Arizona, New Mexico, Southern Nevada Power Area (AZ/NM/SNV) within the Western Electricity Coordinating Council (WECC), a regional entity. These areas contain many balancing authorities (BAs) responsible for dispatching generation, procuring power, operating the transmission grid reliably and maintaining adequate reserves. Although the BAs operate autonomously, some have joint transmission-planning and reserve-sharing agreements.

The NWPP is composed of all or major portions of the states of Washington, Oregon, Idaho, Wyoming, Montana, Nevada and Utah, a small portion of Northern California and the Canadian provinces of British Columbia and Alberta. This vast area covers 1.2 million square miles. It is made up of 20 BAs. The peak demand is 54.5 GW in summer and 63 GW in winter. There are 80 GW of generation capacity, including 43 GW of hydroelectric generation.

**PJM**

The PJM Interconnection operates a competitive wholesale electricity market and manages the reliability of its transmission grid. PJM provides open access to the transmission and performs long-term planning. In managing the grid, PJM centrally dispatches generation and coordinates the movement of wholesale electricity in all or part of 13 states (Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia) and the District of Columbia. PJM’s markets include energy (day-ahead and real-time), capacity and ancillary services.

PJM was founded in 1927 as a power pool of three utilities serving customers in Pennsylvania and New Jersey. In 1956, with the addition of two Maryland utilities, it became the Pennsylvania-New Jersey-Maryland Interconnection, or PJM. PJM became a fully functioning ISO in 1996 and, in 1997, it introduced markets with bid-based pricing and locational market pricing (LMP). PJM was designated an RTO in 2001.

**Southeast**

The Southeast electricity market is a bilateral market that includes all or parts of Florida, Georgia, Alabama, Mississippi, North Carolina, South Carolina, Missouri and Tennessee. It encompasses all or part of two NERC regions: the Florida Reliability Coordinating Council (FRCC) and the Southeastern Electric Reliability Council (SERC). Utilities in the Southeast are vertically integrated and virtually all the physical sales in the Southeast are done bilaterally. Within the Southeast, the resource mix varies between the NERC subregions. The FRCC relies primarily on natural gas, while the rest of the Southeast has historically primarily utilized coal and nuclear plants. However, natural gas electricity has become more economic in recent years for generation and continued to gain an increasing share of the fuel usage.

The Florida Public Service Commission’s (PSC) competitive bidding rules require investor-owned utilities (IOUs) to issue requests for proposals for any new generating project of 75 MW or greater, exclusive of single-cycle combustion-turbines. The bidding requirement can be waived by the PSC if the IOU can demonstrate that it is not in the best interests of its ratepayers.

**Southwest**

The Southwest electric market encompasses the Arizona, New Mexico, southern Nevada (AZ/NM/SNV) and the Rocky Mountain Power Area (RMPA) sub-regions of the Western Electric Coordinating Council (WECC). Peak demand is approximately 42 GW in summer. There are approximately 50 GW of generation capacity, composed mostly of gas and coal units.

The Southwest relies on nuclear and coal generators for baseload electricity, with gas units generally used as peaking resources. The coal generators are generally located in close proximity to coal mines, resulting in low delivered fuel costs. Some generation is jointly owned among multiple nearby utilities, including the Palo Verde nuclear plant, a plant with three units totaling approximately 4,000 MW, which has owners in California and the Southwest.

**Southwest Power Pool (SPP)**

Founded as an 11-member tight power pool in 1941, Southwest Power Pool (SPP) achieved RTO status in 2004, ensuring reliable power supplies, adequate transmission infrastructure, and competitive wholesale electricity prices for its members. Based in Little Rock, Ark., SPP manages transmission in portions of fourteen states: Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas and Wyoming. Its membership is comprised of investor-owned utilities, municipal systems, generation and transmission cooperatives, state authorities, independent power producers, power marketers and independent transmission companies.

In 2007, SPP began operating its real-time Energy Imbalance Service (EIS) market. In the same year, SPP became a FERC-approved Regional Entity. The SPP Regional Entity serves as the reliability coordinator for the NERC region, overseeing compliance with reliability standards.

In March 2014, SPP implemented its Integrated Marketplace that includes a day-ahead energy market, a real-time energy market, and an operating reserve market. SPP’s Integrated Marketplace also includes a market for Transmission Congestion Rights. The SPP Integrated Marketplace co-optimizes the deployment of energy and operating reserves to dispatch resources on a least-cost basis.

In 2015, SPP expanded its footprint incorporating the Western Area Power Administration – Upper Great Plains (WAPA-UGP) region, the Basin Electric Power Cooperative, and the Heartlands Consumer Power District. The expansion nearly doubled SPP’s service territory by square miles, adding more the 5,000 MW of peak demand and over 7,000 MW of generating capacity. WAPA-UGP is the first federal power marketing administration to join an RTO.

**Texas (ERCOT)**

The Electric Reliability Council of Texas (ERCOT) serves as an independent system operator, managing the flow of electrical power to 24 million customers in the state of Texas, representing approximately 90 percent of Texas’ electrical load. ERCOT operates a competitive wholesale electricity market, ensuring reliability over more than 46,000 miles of transmission lines, for approximately 550 generating units and for its customers in Texas. Operating as an energy-only market with real-time, day-ahead, and ancillary service markets, ERCOT also performs financial settlement for the competitive wholesale bulk-power market and administers retail switching for 7 million premises in competitive choice areas. Governed by a sixteen member board of directors, subject to oversight from the Public Utility Commission of Texas and the Texas legislator, its members include consumers, cooperatives, generators, power marketers, retail electric providers, investor-owned electric utilities (transmission and distribution providers) and municipal-owned electric utilities.

NCSU research on electric power systems concentrates on the study of emerging technologies such as power electronics, energy storage, renewable and distributed energy sources on the electric power system operation, control and protection. The research is coordinated through two major centers:

Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM) focuses on development of a smart-grid that will enable anybody to integrate new renewable energy technologies into the power grid for a secure and sustainable future. Research involves development or adoption of new power electronics, communication, and control technologies to demonstrate and prototype such a system. More info is at: http://www.freedm.ncsu.edu/

Advanced Transportation Energy Center (ATEC) focuses on development of fundamental and enabling technologies that will facilitate the electric power industry to actively manage and control large amount of plug-in hybrid vehicle (PHEV) and plug-in electric vehicle (PEV). More info is at: http://www.atec.ncsu.edu/

Bistline, John E. and Rai, Varun, The Role of Carbon Capture and Storage in Greenhouse Gas Emissions Reduction Models: A Parametric Study for the U.S. Power Sector (June 1, 2009). Program on Energy and Sustainable Development (PESD) Working Paper No. 85, Energy Policy, Vol. 38, No. 2, pp. 1177-1191, February 2010 , Available at SSRN: https://ssrn.com/abstract=1431172 or http://dx.doi.org/10.2139/ssrn.1431172

This paper analyzes the potential contribution of carbon capture and storage (CCS) technologies to greenhouse gas emissions reductions in the U.S. electricity sector. Focusing on capture systems for coalfired power plants until 2030, a sensitivity analysis of key CCS parameters is performed to gain insight into the role that CCS can play in future mitigation scenarios and to explore implications of large-scale CCS deployment. By integrating important parameters for CCS technologies into a carbon-abatement model similar to the EPRI Prism analysis (EPRI, 2007), this study concludes that the start time and rate of technology diffusion are important in determining emissions reductions and fuel consumption for CCS technologies. Comparisons with legislative emissions targets illustrate that CCS alone is very unlikely to meet reduction targets for the electric-power sector, even under aggressive deployment scenarios. A portfolio of supply and demand side strategies is needed to reach emissions objectives, especially in the near term. Furthermore, model results show that the breakdown of capture technologies does not have a significant influence on potential emissions reductions. However, the level of CCS retrofits at existing plants and the eligibility of CCS for new subcritical plants have large effects on the extent of greenhouse gas emissions reductions.

Lowder, B. Tim, General Electric's Quest for Global Competitive Advantage: In Search of Structural and Strategic Alignment (December 8, 2006). Available at SSRN: https://ssrn.com/abstract=951103 or <http://dx.doi.org/10.2139/ssrn.951103>

The focus of this research paper is to perform a structural analysis of General Electric (GE) as it strives to attain global competitive advantage in light of new leadership strategies. In addition, the paper presents recommendations to enable a structural design that establishes alignment between General Electric's (GE's) structure and its newly established strategies. GE's new strategies focus on customer value, innovation, leadership in technology, commercial excellence, globalization, and market segmentation based on growth leadership. First, the analysis will focus on factors that influence the level of synthesis between GE's technical core and its peripheral components. Second, the paper identifies and evaluates several interrelated sub-systems relationships that impacts the synergistic alignment between GE's technical core and its peripheral components. These interrelated sub-system relationships provide the key to establishing a foundation for determining an optimal structure aligned with GE's strategies. In summary, this paper evaluates GE's current technical core and peripheral components from a systems perspective to make structural recommendations on how to best align GE's structure with its newly established strategies.

**Firefighting and Home Fire Hazards, Home Electrical Hazards**

1. Home Smoke Alarms
2. Home Fire Sprinklers
3. Carbon Monoxide
4. Home Fire Escape
5. Home Cooking
6. Electrical Burns
7. Heating
8. Smoking Tobacco
9. Electrical
10. Lightning
11. Candles
12. Matches and Lighters
13. Outdoor Burning
14. Wildfires
15. Medical Oxygen
16. Flammable and Combustible Liquids
17. Battery Safety
18. Portable Fire Extinguishers and Firefighting
19. Clothes Dryers
20. Pet Fire Safety
21. Youth Firesetter

**Community Groups**

1. Chamber of Commerce/Business
2. Faith Community
3. Federal and State Land Agencies
4. Fire Department
5. Local Utilities, Electric and Water and Natural Gas
6. Park District
7. Private Land Trusts
8. School District
9. Street and/or Public Works Department
10. Water District

**Fires in Structures:**

1. Under Construction
2. Under Major Renovation

**Fires in Structures Under Construction**

1. Cooking Equipment
2. Electrical Distribution and Lighting Equipment
3. Heating Equipment

**Construction Site Fire Safety, NFPA Fact Sheet**

**Risk Factors for Buildings Under Construction**

-complying with NFPA 241 helps you manage and mitigate risks that can lead to catastrophic and costly events at construction sites

-from a carelessly disposed cigarette to failure to properly store or dispose of combustible materials, these fires often result from lack of awareness and understanding of fire risks and consequences, and they are almost always preventable

1. Carelessly Disposed Cigarette
2. Failure to Properly Store or Dispose of Combustible Materials

**Risk Factors for Building Under Construction**

1. Insufficient Fire Protection Systems, not as many as they will have once the building is completed; sprinklers, smoke detectors, fire alarms, not yet installed and operational
2. Intentionally Set Fires from vandalism and theft and trespassing, due to construction sites being unsecured and vulnerable
3. Ignition Sources on are common on construction sites; equipment (heaters) and hot work (welding, cutting, grinding, smoldering, roofing); any lapse in adherence to safety procedures may result in damages to the site itself as well as to adjacent buildings and can put site workers, civilians, and first responders at risk of injury and death

**Key Issues**

1. NFPA 241 must be followed regardless of the building materials being used
2. Construction sites must be safeguarded around the clock, not just when work is being done
3. Failure to comply with NFPA 241 may result in work stoppage, delays, and/or costly fines, even if you avoid an incident, or only experience a small incident
4. Far-reaching, long-term economic and other community impacts, the impacts of construction site fires beyond those of potential personal injury, death, and direct dollar loss

**NFPA 241, Application and Compliance**

1. Temporary construction, equipment, and storage
2. Processes and hazards
3. Utilities
4. Fire protection
5. Safeguarding various operations, such as:
6. Construction and alterations
7. Roofing
8. Demolition
9. Underground operations

**Documents Requiring Compliance with NFPA 241**

1. NFPA 1, Fire Code
2. NFPA 5000, Building Construction and Safety Code
3. IBC, International Building Code
4. IFC, International Fire Code
5. IRC, International Residential Code

**Did You Know?**

If you live in a state where NFPA 1, the IFC, or the IBC has been adopted, the requirements of NFPA 241 are not optional, they must be followed, regardless of job size

**What You Should Know**

1. Code Official; you must know and enforce the requirements of NFPA 241 on the building owner
2. Fire Chief; you must be involved in the creation of a prefire plan and train all personnel on the plan
3. Building Owner, with a building under construction, alteration, or demolition; you must have a (FPPM) fire prevention program manager per NFPA 241
4. Contractor, or someone working on a job site; you must follow NFPA 241 and the direction of the FPPM

**Construction Site Safety During Emergencies, NFPA Fact Sheet**

-NFPA 241, not specifically intended for demobilization efforts

-AHJ, Authority Having Jurisdiction; owners and contractors should always check with their AHJ for specific requirements and final approval

**In Emergencies, 3 Critical Questions**

1. What existing conditions are currently on-site?
2. What key requirements should be considered?
3. How do these buildings properly resume operations when cleared to do so?

**Critical Sites List**

1. Construction, Alteration, or Demolition
2. Roofing Operations
3. Under-Ground Operations
4. Tall-Timber Structures

**Existing Condition Questions to Ask NFPA 241\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. Temporary offices and sheds; NFPA 4.2; Are these units properly separated from other structures, such as dumpsters or trailers?
2. Waste disposal; NFPA 5.4; Has all waste been properly removed from the site? If left on the site, where is it located, and when will it be removed?
3. Storage of flammable/combustible liquids/gases; NFPA 5.5; Have these liquids and gases been removed from the site or properly secured? Does the AHJ have specific requirements for the storage of materials left on-site?
4. Command posts; NFPA 7.5.1; Is a command post area set up and available for use by the AHJ, and what items are found at this location? Is a key box required?
5. Acces roadways; NFPA 7.5.3; Are access roadways clear and unobstructed? Are these surfaces able to provide access and withstand the requirements of fire department apparatus?
6. Standpipes; NFPA 7.6; Where required, what is the condition of the standpipes on-site?

**8 Key Requirements to Consider**

1. ***Fire Safety Program***
2. **Good Housekeeping**
3. What is the current status of your site?
4. Are loose combustible materials overflowing from dumpsters, stacked in certain areas, or lying loosely?
5. Is there a timely plan in place to safely remove these items?
6. Has a simple visual inspection been completed?
7. **On-Site Security**
8. Is your site adequately protected/secured, including proper fencing?
9. If security is provided, is it clear what the expectations are at off-hours? Ensuring that proper protocols are in place can help limit unwanted entry, property loss, or injury.
10. **Fire Protection Systems**
11. What is the status of the fire protection systems on the site as it currently stands?
12. Is access to the water supply valves or fire department connections (FDCs) readily accessible, even when a site is shut down?
13. **Rapid Communication**
14. Who is on-site?
15. Who is not on-site?
16. Is there a good communication plan in place that includes up-to-date contact information to share with relevant stakeholders?
17. **Protection of Existing Structures**
18. In the efforts to prepare another site, have any structures, roadways, or neighbors potentially been compromised?
19. Are the site borders clearly marked to maintain access for the fire department?
20. ***FPPM, Fire Prevention Program Manager***
21. ***Fire Protection Devices***
22. Has the FPPM ensured that enough devices, such as fire extinguishers, are on-site?
23. Have the workers that remained on-site been trained properly to use these devices?
24. Have these devices been properly maintained and serviced accordingly?
25. ***Inspections***
26. The FPPM is responsible for inspections of the site, as determined by the AHJ. How is the site still being inspected?
27. Who is performing the inspection?
28. Are records being maintained?
29. How are issues being communicated, and to whom?
30. ***Impairments***
31. Are there any impairments to any fire protection/fire alarm systems?
32. If so, what is the plan to address the impairment(s)? The FPPM should be aware of such impairments and work with the proper parties to actively address any issues.

**Resume Operations, 3 Key Actions Items**

-the first step is to consult with the local AHJ for specific requirements

1. Develop a fire safety program
2. Appoint a fire prevention program manager to execute the fire safety program
3. Establish communications with their local fire department regarding a prefire plan
4. AHJs are often seen as only building and fire officials
5. Federal, State, and Local authorities, and certain Insurance Providers
6. Sharing of pertinent information with all relevant parties should be established and continued for the duration of the project

**What You Should Know**

1. Code Official; know and enforce the requirements of NFPA 241
2. Building Owner, Facility Manager, FPPM; have a fire safety program
3. Contractor or Worker on Job Site, must follow the fire safety program

**Hot Work Safety, NFPA Fact Sheet**

-An Ignition Source, the risk with hot work of spontaneous fires is high because it introduces a hazard, an ignition source

-the number one safety recommendation is to determine whether there is an alternative to hot work, and by avoiding hot work, you minimize the risk

-fires can start after the hot work is complete, so the fire watch must remain on site for a minimum of 60 minutes to monitor for soldering fires, per NFPA 51B

-the permit authorizing individual could require the fire watch to remain on site longer depending on the conditions of the work site

**What is Hot Work?**

1. Work involving burning, welding, or a similar operation that is capable of initiating fires or explosions
2. Activity involving flame, spark production, or heat
3. Welding and allied processes include arc welding, oxy-fuel gas welding, open-flame soldering, brazing, thermal spraying, oxygen cutting, and arc cutting

**Hot Work Hazards and the Fire Triangle**

1. Oxygen; is present in the ambient air; unsafe practices involving pure oxygen can cause oxygen enrichment (over 22% by volume) in the workplace
2. Fuel; includes anything that can be ignited, any common fuel source
3. Construction materials such as wood, plastic, insulation, roofing materials, including those in concealed spaces
4. Flammable and combustible liquids or gases such as fuel, paint, cleaning solvents
5. Simple combustibles such as rags, paper, cardboard, lumber, furnishings
6. Ignition Sources; can be as simple as the hot work itself

-ignition results when any heat source sufficient to ignite a fuel does so, and can occur through the direct or indirect application of heat

1. Direct Application of heat; welding, cutting, burning
2. Indirect Application of heat; heat conducted through metal surfaces to fuel sources on the other side (through to the other side of a bulkhead); and sparks traveling to a distant fuel source (to a pool of liquid or other combustible material)

**NFPA 51B, Standard for Fire Prevention During Welding, Cutting, and Other Hot Work**

-NFPA 51B, is required by reference, and therefore, compliance is not optional

-OSHA references NFPA 51B, in 29 CFR 1910 Subpart Q

-NFPA 1 Fire Code, requires compliance with NFPA 51B in Chapter 41

**Ways to Minimize Hot Work Hazards, NFPA 51B**

1. Recognize; determine if fire risks exist before hot work is started
2. Evaluate; determine if hazards are present, especially hazards that could fuel a fire (flammable and combustible liquids or gases and simple combustibles)
3. Control; take appropriate steps to eliminate or minimize the hazards

**Hot Work Permit**

-helps the permit authorizing individual, the hot work operator, and the fire watch to recognize potential hazards

-areas can be protected with the use of welding pads, blankets, or curtains, clearing combustibles from a 35-ft (11-m) radius space around the hot work, or moving the hot work to an area free of combustibles

**Alternatives to Hot Work**

1. Screwed , flanged, or clamped pipe
2. Manual hydraulic shears
3. Mechanical bolting or pipe cutting
4. Compressed air-actuated fasteners

**What You Should Know**

1. Code Official; know and enforce the requirements of NFPA 51B
2. Building Owner, Facility Manager; must have a procedure in place for documenting hot work hazards and for advising all contractors about site-specific potential fire hazards; you also need to know any jurisdiction-specific regulations you need to comply with
3. Contractor, or someone working on a job site; know the specific combustible hazards within a client property, where manual fire-fighting tools are located, and where hot work is not allowed

**Fires in Structures Under Construction or Renovation**

Kevin Sleem and Lindsey Campbell, NFPA Research Bulletin, NFPA 241

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1. Construction Sites; Structures Under Construction
2. Renovation Sites; Structures Under Major Renovation
3. 1% each, reported structure fires at construction sites and renovation sites
4. Why is there a greater percentage of fires in structures under construction for residential properties than commercial properties, even by 75%? These residential properties fires also contributed the largest shares of deaths, injuries and direct property damage.
5. The leading cause of fires on construction sites was faulty cooking equipment, 22% and ⅓ of injuries, which tend to be minor; and 10% intentionally set fires which led to 32% of property damage
6. The leading cause fires on renovation sites was electrical distribution and lighting equipment, at 25% of all fires
7. Fires on construction sites were highest in the cold weather months of November, December, January, and March, and during afternoon and early evening, though fires occurring between midnight and 4 AM accounted for 33% of direct property damage
8. Renovation Sites, Direct property damage on renovation sites was 20% in regards to leading item first ignited, which was a structural member or framing
9. Construction Sites, items first ignited and property damage, fires in which a structural member or framing were first ignited accounted for two-fifths of property losses

**Leading Ignition Sources**

**Construction Sites**

1. Electrical failures or malfunctions
2. Abandoned or discarded materials or products
3. Heat sources too close to combustible materials

**Renovation Sites**

1. Electrical failures or malfunctions
2. Heat sources too close to combustible materials

**Leading Heat Sources, Renovation Sites**

1. Arcing
2. Spark, ember, or flame from operating equipment
3. Radiated or conducted heat from operating equipment
4. Unclassified heat from powered equipment

**Fires in Structures Under Construction**

-32% of these fires were confined fires, and the presence of construction workers at construction sites who can detect and extinguish fires before they have an opportunity to spread may explain why many of these fires were confined fires

1. 76%, Residential
2. 7%, Mercantile of Business
3. 5%, Outside or Special Property
4. 4%, Storage
5. 3%, Assembly
6. 2%, Educational

**Timing of Fires, Cold Winter Months**

-it is important at construction sites, where combustible and flammable materials are present-that equipment be used for its intended purpose

-it is also important that temporary heaters are selected and used with fire safety in mind

-care is needed to ensure that temporary heaters are properly set up and that areas around them are kept clear of combustible materials

**Leading Items First Ignited in Structure Fires Under Construction**

-roughly one in 10 fires involved the ignition of waste materials at the construction site, including rubbish, trash, waste, or oily rags

**Fires in Structures Under Major Renovation**

-19% of these fires were confined fires, although big fires are what make the news

-little month to month variation in fires in renovation sites, not the cold months, like construction sites, potentially because there is less need for temporary heating equipment or other mechanized equipment in renovation projects

-as with structures under construction, the peak periods for fires in structures under major renovation was during afternoon (12-4) and early evening (4-8), though fires occurring between midnight and 4 AM accounted for 23% of direct property damage

**Leading Items First Ignited in Structure Fires Under Major Renovation**

-structural elements accounted for over one-third of items first ignited in structures under major renovation, including, structural members or framing, exterior wall coverings or finishes, insulation within structural areas, and unclassified structural components

-No equipment was involved in one-fifth of fires

**Discussion**

-on average, firefighters responded to just over 10 fires in structures under construction and seven fires in structures undergoing major renovation each day between 2013 and 2017

**Most Common Causes of Construction and Renovation Fires**

1. Electrical Distribution and Lighting Equipment; NEC, National Electrical Code, ensure that temporary electrical service lighting follows installation requirements set forth in the NEC, that electrical equipment is maintained and regularly inspected, that use of extension wiring is kept to a minimum, and that machinery and equipment do not overload available circuits
2. Heating Equipment; ensure that unauthorized temporary heaters are restricted from the worksite, that heaters permitted on the worksite are placed at safe distances from combustible and flammable materials and used in conformity with manufacture instructions, and that heaters are regularly checked to ensure that they are being safely operated and do not constitute a hazard (such as being overturned)
3. Cooking Equipment; probit the use of cooking equipment (such as hot plates or grills) or the use of improvised heating devices for warming food at the construction site (in designated areas, with appropriate distance barriers)
4. Hot Work Activities, Torch, Burner, or Soldering Iron; require a permit system for hot work activities and enforce a 30 minute (or longer) cool-down interval following use of torches, burners, or soldering irons
5. Intentional Cause, Arson; safeguard construction sites with fencing or other controls, such as lighting or after-hours security personnel, as needed

**NEC, National Electrical Code**

**POWER SYSTEMS ENGINEERING: A CAREER ON THE GRID**

**UC Riverside, Online Master of Science in Engineering** <https://engineeringonline.ucr.edu/blog/power-systems-engineering-a-career-on-the-grid/>

Power systems have a long history in the U.S. that dates back to 1882, when Thomas Edison founded the first electric utility owned by investors. According to the Smithsonian Institution, what is considered the first large-scale distribution of electrical power occurred more than a decade later when water pouring over Niagara Falls was diverted to turbines attached to two 5,000-horsepower generators. Since then, the way that electricity is created and distributed has gone through dramatic iterations, but the value of the commodity has only increased.

Today, engineers are often tasked with the responsibility of designing, managing and improving these critical systems. As an electrical engineer, a deep understanding of power systems and the ways that they provide energy to communities across the nation through a master’s degree will help you to succeed in your field after graduation.

**What is an electric power system?**

An electric power system is a network of pieces that combine to process and distribute electrical power. While this can take many forms, the most common are the large networks – sometimes known as “the grid” – that supply communities with electricity. These networks typically contain a source – usually a generator – which creates power that is passed through a transmission system and is delivered to individual homes and businesses through some form of distribution system.

The term “electric power system” is not to be confused with “power electronics,” the latter of which is a more broad – though closely related – concept that describes the study of converting electrical power from one form to another.

**Engineering and the steady state**

These electric systems typically create power through synchronous generators. The stability of these generators is intertwined with their ability to return to what is known as the steady state – or the system’s equilibrium. In electronics, the system must have the ability to return to this equilibrium state without losing synchronism.

The balance of power systems is typically categorized by one of three classifications of stability, the differences of which are particularly significant in scientific research:

1. Dynamic stability looks at a system’s ability to return to its original state after experiencing continual small disturbances.
2. Transient stability involves the study of a power system after it has experienced a major disturbance.
3. Steady state stability is the ability of a system to return to a stable state after a small disturbance has occurred.

It is also important to note that steady state systems’ outputs operate independently of time.

**Security assessment in electrical engineering**

As in much of engineering, the practical application is critical when you work in the field. This typically brings engineers back to the power grids that convert and distribute electricity to the millions of people who live in the U.S.. When such a large amount of energy is being created and distributed through systems, a major challenge you will face is the threat of brownouts or blackouts. A blackout is a complete outage of power in a particular area, while a brownout is a partial reduction in the voltage or capacity of the system, which is only temporary. Brownouts are more common in electrical power systems, but blackouts are the more problematic of the two, as they can lead to significant disruptions.

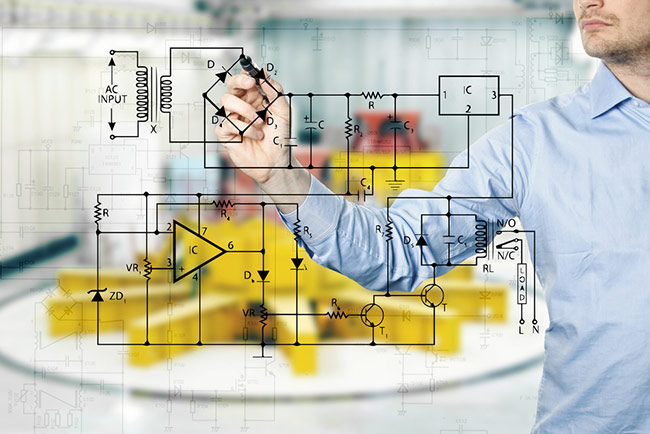
When you work in the field of electrical engineering, one answer to this threat is the use of security constrained optimal power flow, or SCOPF. This method offers an additional set of parameters that limit some of the conditions at which the system can operate it. Common constraints that you may use include voltage magnitude, voltage stability and angle stability of the power supply. As an electrical engineer, part of your role in the workplace may include assessing these security constraints to determine the most efficient conditions to be used in industrial applications to ensure that electrical power is delivered in the most cost-efficient manner. That may include running hundreds of simulations, looking at worst-case scenarios to guarantee the safety and efficiency of the system.

An alternative to SCOPF is optimal power flow, or OPF. As opposed to SCOPF, which provides additional parameters to ensure security, OPF systems simply offer the best flow for a particular configuration, without taking extra constraints into consideration. It is consequently a simpler system that does not involve making as many assumptions or checking a large number of parameters. However, the system may not be as secure as one that uses SCOPF. As an engineer, you may find yourself in situations in the workplace where you are tasked with determining which option is better for a particular scenario, with respect to the financial concerns of your employer.

**The market analysis of power systems**

The operation of large-scale power systems requires more than simply technical knowledge and an understanding of electrical engineering. Though you may not expect to use economics as an engineer, market analysis is important for determining the financial component of running these systems. In large-scale power distribution in particular, companies need to know not only how much power to release, but how much they should charge consumers.

If you are considering a career in power systems, electrical engineering knowledge is clearly a must. However, having a grasp of the economic factors that go into play through market analysis is also beneficial. Consequently, many higher level courses will cover the topic when you pursue a master’s degree. Depending on your position after graduation, you may find that working as an electrical engineer requires a deeper knowledge of business and economics than you had anticipated.



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**Engineering careers in power systems**

Whether you are currently pursuing a higher degree or considering enrolling in a master’s program, your job prospects upon completing your education are likely a high concern. Positions in electrical engineering in general currently have a promising outlook. According to the U.S. Bureau for Labor Statistics, the average salary for one of these positions is $95,230 per year, and the number of positions is not expected to decline through 2020. However, because the bureau predicts little growth in the overall number of jobs between 2014 and 2024, having the experience and knowledge provided by a master’s degree can help set you apart in what could prove to be a competitive field.

While a background in power systems will aid you in most any position as an electrical engineer, there are also a number of more specialized roles that are available to you when you have this specific expertise. Some of these positions include titles such as:

1. Electrical power systems engineer
2. Electrical engineer infrastructure and power distribution
3. Power supply engineer
4. Line design engineer
5. Power transmission and distribution engineer
6. AC-DC power systems engineer

When pursuing a career in power systems as an engineer, you will most likely end up working for an academic institution’s lab or at a plant owned by a power company. Though you may sometimes be called on to work evenings or night shifts, positions in this field typically operate during normal weekday hours.

Your responsibilities when working in power systems will likely include different facets of designing, creating, testing and operating these systems to ensure maximum operational efficiency and cost-effectiveness. Depending on your role, you may also work on the growing application of integrating renewable energy strategies and technologies into these systems. As the U.S. government makes a push toward green energy, innovation is needed to find new ways to power the nation’s systems without relying on fossil fuels and other limited resources.

If you are currently pursuing your education or working as an electrical engineer and considering shifting to a more specialized field, the time is right to consider a career in power engineering. According to a 2011 survey by the Center for Energy Workforce Development, the electrical utility workforce is rapidly aging. In fact, the report predicted more than 60 percent of workers could retire or leave by 2020. As the workforce filling these jobs decreases, more positions in power engineering will open up, providing a number of new opportunities for recent graduates to fill.

In addition to providing a career that is both challenging and rewarding, working in power systems has financial incentives for engineers. PayScale reported that positions specifically in power systems engineering in the U.S. generally come with an annual salary between $60,722 and $103,832.

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Access Charge – A fee all market consumers pay for withdrawing energy from the local Independent System Operator (ISO) Controlled Grid. The access charge is designed to cover a portion of the utility?s transmission revenue fees that are not covered by the costs from the variable use charge.

Active Solar Energy – Solar radiation that is captured by an active solar energy system and used to create electricity, heat or hot water.

Adjustment Bid – Bids utilized by individual Independent System Operators as a tool to adjust supply or demand during anticipated peak consumption times.

Advanced Metering Infrastructure – A multi-faceted system of different data management systems, smart meters and communication networks that allows for more transparent, two-way communication between utilities and their customers.

Adverse Hydro Conditions- A situation when water conditions limit the amount of hydroelectric power.

Aggregators – An organization in charge of accounting, planning, billing, scheduling and settlement issues for energy deliveries. The main goal of an aggregator is to work with both the buyers and sellers to bring together generators and customers in an effort to buy and sell bulk power orders.

Air Pollution – When the air is laden with gasses, pollutants and unwanted particles that compromise the purity of the air. Typically air pollution is caused by automobile exhaust, factories and other human actions.

Alcohol Fuels – A specific type of liquid chemicals that can be used as a fuel source. All alcohol fuels contain a combination of oxygen, carbon and hydrogen.

Alternating Current – An alternating current, often abbreviated as AC, refers to the flow of electricity that moves between positive and negative charges. Measurements can vary, but in the United States, most electricity distributed to homes moves with an AC rate of at least 60 times per second.

Alternative Energy Sources – Alternative energy sources, also known as renewable energy sources are used to describe anything that can be used to create usable energy besides fossil fuels such as coal, oil and natural gas. Commonly used alternative energy sources are solar, wind, hydro and nuclear energy.

American National Standards Institute – Also known as the ANSI, the American National Standards Institute is a volunteer-run organization that creates guidelines for technology in virtually every industry, including the energy distribution market.

Ancillary Services – In the energy market, ancillary services are any type of service other than scheduled energy service required to maintain the reliability of a system and keep it up to code. This includes coordinating services such as reserve replacement and voltage control.

Angle of Incidence – The angle measured between the direct impact of the sun?s rays and the surface of a solar panel. Solar panels are installed to be perpendicular to the sun?s rays to get the most energy possible and to utilize the best angle of incidence.

Amp – An Amp, which is short for Ampere, is the most commonly used measuring unit to identify how much electricity is flowing through a conductor. An amp represents the flow of the electric current a single item pulls from the source by taking watts divided by volts. For example a 1500, 100 volt blender would pull 10 amps of electricity.

Annual Maximum Demand – The maximum demand for electricity that occurred during a specific calendar year.

Animal Waste Conversion – The process of using animal waste to create energy. Animal waste is referred to as a type of biomass energy.

Appliance Efficiency Standards – Appliance Efficiency Standards were put in place by the state of California as an energy conservation effort designed to regulate the minimum energy performance requirements for California-sold appliances. These standards monitor how energy efficient space heaters, water heaters, air conditioning units, fluorescent lamps and other appliances must be in order to be sold within the state.

Area Load – A number used to describe the total amount of electricity being used at a single point in time by consumer?s in a specific service territory.

Automatic Meter Reading – The technology used to collect billing data on a property?s meter without a physical inspection. This data can then be transferred to the utility company through telephones, power lines, cable, satellite signals or radio frequency.

Average Cost – A utility?s revenue requirement divided by their sales. Average cost typically includes the amount needed to cover distribution lines, transmissions and other facilities.

Average Demand – The amount of energy needed to serve a geographical area over a certain period of time.

Average Hydro – The amount of water, including rain, snow and runoff conditions needed for hydroelectric generation.

Avoided Cost – The amount of money a utility would incur if it weren?t for an independent generator or another outside energy service option. These rates are at times used to determine the power purchase price for independent suppliers looking to buy from local utilities.

Avoided Cost, Regulatory – A term used to describe the amount of money that an electric utility needs to spend to produce or purchase power that it has purchased instead from an outside small-power producer or co-generator. There are federal laws that govern how much a facility can earn on these transactions.

B

Base Load – The lowest amount of power needed during a specific season or year.

Base Loat Unit – A facility that generate power at a level that is intended to run constantly at near-capacity levels.

Baseline Forecast – A prediction of how much future energy will be needed for a certain project or area. This forecast does not take future conservation programs into account.

Base Rate – The portion of the total electric rate that covers general business costs.

Bilateral Contract – A binding agreement between two parties that governs the purchase and sale of electricity products.

Blackout – A complete power loss that impacts numerous energy consumers over a large territory.

Bonneville Power Administration (BPA) – One of the five different federal power marketing administrations. The BPA serves customers in Idaho, Oregon, Washington and parts of Wyoming and Nevada. The company sells low-cost energy products created by federal hydroelectric dams to municipal and agricultural users.

British Thermal Unit (Btu) – The standard unit to measure heat energy.

Broker – An individual retail agent in charge of buying and selling power to consumers.

Brownout – A planned and controlled power reduction put in place by a utility. A brownout decreases the amount of voltage in the power lines, resulting in customers receiving a weaker electric current through their property. Most properties typically do not notice the difference during a brownout.

C

Capacity – The amount of electric power for a generating unit. There are several types of electricity capacity:

Dependable Capacity – A system?s ability to carry electricity for a specific period. Dependable capacity is determined by capability, operating power factor or weather.

Installed Capacity – The manufacturer-rated electricity capacity of equipment, including items like generators and turbines.

Peaking Capacity – The electricity capacity of generating equipment, meant to be used during the highest loads either daily, weekly or seasonally.

Purchased Capacity – The amount of electricity available for purchase outside a specific system.

Reserve Capacity – The excess generating capacity available to meet high power demands or to generate power during unplanned outages.

Combined Cycle Plant – A station that generates electricity to use waste heat from gas turbines to create steam.

Converter – A piece of technology that takes a potential energy fuel and transfers it to a different form of energy from a source such as heat or motion.

Cooperative (Electric Utility) – A joint effort organized by consumers to bring services from an electric utility to a certain area.

D

Daylighting – The use of sunlight to replace or supplement electric lighting. Daylighting is controlled by a system that varies the light output of an electric lighting system.

Demand – The amount of electricity used at a single given time, or over a designated period. Typically electricity demand is measured either in kilowatts (kW) or megawatts (MW).

Demand Charge – A fee paid by larger energy consumers to cover its peak usage level.

Department of Energy (US D.O.E) – A federal department put in place by the Department of Energy Organization Act to consolidate energy functions and create a balanced energy policy.

Deregulation – When a specific market stops having the state regulate their market, meaning consumers are able to choose who they purchase electricity from.

Direct Access – A retail customer?s ability to purchase commodity electricity directly from a wholesaler rather than a distributor.

Direct Current (DC) – Electricity that flows in a continuous pattern in the same direction.

Direct Energy Conversion – The process of producing electricity from an energy source to produce a direct current. Direct conversions do not have any moving parts.

Direct Solar Gain – When solar energy is collected through windows, walls and skylights, in a building as heat from the sun.

Distributed Energy- A term used to describe an energy system that produces power for dozens of small sites across a grid, as opposed to delivering energy to a single site, like a power plant.

Distribution Charge or Delivery Charge – A fee charged to electricity customers to cover the cost of delivering energy of the utility?s power lines. No matter how much electricity a customer uses or who supplies that energy, the distribution, or delivery charges remain the same.

Distribution – The process of delivering electricity to a property through low voltage distribution lines.

Distribution System- The stations, power lines and transformers that convey electricity from high-powered transmission lines directly to consumers. Also known as a GRID.

Distribution Utility – A regulated electric utility that creates and maintains distribution wires that connect the transmission grid to the customer.

Dry Steam – A type of geothermal energy used to produce energy. It is one of the primary forms used in California.

E

Economy Energy (Electric Utility) – A term used to describe the electricity purchased by one utility from another utility to take the place of more expensive electricity that would have cost more to produce.

Electricity Facts Label (EFL) – This label details important information about a customer?s energy supply. This includes contract terms, source of power generation, prices and emission levels. All energy suppliers need to provide an EFL to their consumers.

Electric Generator – A piece of equipment that can convert heat, chemicals or mechanical energy into electricity.

Electric Radiant Heating – A heating system that uses electric resistance to create heat.

Electric Utility – An individual or state-run agency that has a monopoly franchise that sells energy to consumers.

Energy Budget – A budgetary requirement in Building Energy Efficiency Standards for a proposed building so it can be designed to only use a certain amount of British thermal units (Btus) per year per square feet space.

Energy Charge – The amount of money charged to an energy consumer to cover the amount of kilowatt hours that customer consumed.

Energy Consumption – The amount of energy a customer uses, excluding their own electric generation and distribution losses.

Energy Efficiency – A process of using different programs and technology to use a smaller amount of electricity to perform the same function.

Energy/Fuel Diversity – A policy that promotes the development of energy technology in an effort to diversify energy supply sources, to reduce dependence on conventional fuels.

Energy Management System – A digital control system that can help regulate the energy consumption of a building, including HVAC, water heating and lighting systems.

Energy Reserves – A part of all energy resources that is available for use at an affordable price.

Energy Resources – Any source of energy that can be used to create electricity.

Energy Services Company (ESCO) – An ESCO is another term for an energy supplier. These companies have the ability to purchase electricity for their customers and act as a middleman between the company generating electricity and the local utility who delivers that energy.

Environmental Protection Agency (EPA) – An agency created in 1970 that is responsible for protecting the environment. The agency protects the environment through its efforts to control and remove pollution through enforcement, research and monitoring efforts.

Exchange (Electric Utility) – An exchange within an electric utility depicts an agreement between two utilities regarding the purchase, sale and trade of power. Typically the term exchange is used to relate to kilowatt capacity or kilowatt hours.

Exports (Electric Utility) – In an electric utility, exports are used to describe the power capacity or energy that a utility is required to supply outside of its own service area. Exports are not covered by general rate schedules.

Extra High Voltage – When voltage levels are higher than the normal amounts typically used on transmission lines. Typically, when lines reach 345,000 volts or higher, they are described as extra high voltage.

F

Federal Energy Regulatory Commission (FERC) – An independent regulatory commission that serves as part of the U.S. Department of Energy and presides over energy produces that sell or transport fuels.

Feed-In Tariff – A renewable energy policy that offers guaranteed payments to individuals as a result of the amount of renewable energy that they produce.

Flat Plate – A piece of black painted metal used to collect solar energy. This plat faces the sun as a way to absorb the heat from the sun.

G

Generation – This term is used to describe the production of electricity from a variety of sources. Electricity can be generated from natural gas, coal, nuclear energy services, geothermal power, or renewable resources such as sun, wind or water.

Generating Station – Another term used to describe a power plant.

Geothermal Energy – A natural form of heat within the earth that can be captured as a source to produce electric power.

Gigawatt (GW) – A measuring unit equal to one thousand megawatts (1,000 MW) or one million kilowatts (1,000,000 kW), or one billion watts (1,000,000,000 w) of energy.

Green Energy – A type of environmentally-friendly energy that is generated from sustainable resources and converted into electricity. Typically, this energy comes from renewable sources such as water, wind power or the sun.

Greenhouse Gases – Gasses that are released into the atmosphere when fossil fuels such as coal and oil are burned. Typical greenhouse gasses are carbon dioxide and methane. These gases can contribute to changes in the climate as they trap heat in the atmosphere and can ultimately cause serious environmental damage.

Grid – An electrical distribution network, also known as power grids that are governed by the utility companies.

H

Heliothermal – A process that utilizes the sun?s rays to create heat.

Hybrid System – This is a system that combines two or more power-generating methods into a single system. For example, a system could user solar power put have a generator as a backup.

Home Energy Assistance Program (HEAP) – A direct payment program that helps eligible properties with financial need to receive affordable heating and cooling assistance for their homes.

HVAC (Heating Ventilation and Air Conditioning) – A system within a property that is in control of heating, ventilation and cooling.

Hydroelectric Power – Electricity creates by falling water that goes into a turbine generator to produce energy.

I

Imports (Electric Utility) – The energy or power capacity obtained by one utility from another utility under a purchase or an exchange agreement.

Independent Power Producer (IPP) – An entity that generates power that is purchased from an electric utility at wholesale price. The utility will then resell this power to customers. Independent Power Producers do generate power, but they are not utilities, which means they do not own the transmission lines used to transmit any power they generate.

Insolation – The complete amount of solar radiation, including direct, diffused and reflected radiation that strikes a particular exposed surface.

Interchange (Electric Utility) – An Agreement between interconnected utilities where they buy, sell and exchange power between themselves.

Interconnection (Electric Utility) – Linking transmission lines that connect two utilities. This allows power to be moved back and forth between multiple entities.

Interruptible Service (Electric Utility) – An agreement that allows the governing supplier to stop electric service at any given time.

Intertie – An energy transmission line that connects two or more electric power systems within a certain region.

Investor-Owned Utilities (IOU) – A privately-owned company that provides a utility to a specific service territory. These companies are owned by stockholders and are meant to generate a profit.

Independent System Operator (ISO) – An independent, neutral operator in charge of maintaining a balanced energy grid. The IOS is responsible for ensuring the grid?s load matches the system?s available resources.

K

kBtu – An amount of energy equal to 1,000 Btus.

Kilovolt (kv) – An amount of energy equal to 1,000 volts. Typically distribution lines in residential areas are 12 kv.

Kilowatt (kW) – A measurement unit of electricity equal to 1,000 watts. This unit measures the amount of energy produced or consumed by a single device.

Kilowatt Hour (kWh) – The most frequently used measuring unit to determine the amount of electricity consumed over a given period. The kilowatt measures the amount of electrical power, while the time is measured in hours.

L

Layoff (Electric Utility) – The excess capacity of a generating unit. The layoff is available for a limited period of time, depending on the stipulations put in place by the power sales agreement.

LED (Light-Emitting Diode) – A diode that emits light once the appropriate voltage is applied. The light is used in a variety of settings as it utilizes less energy than other types of lights.

Load – The amount of electrical power given to an end user to meet their needs. A load can also be used to describe an end-use device or customer that consumes power.

Load Management – A process used to reduce power demand at peak load times.

Losses (Electric Utility) – The amount of electric energy that is wasted during a power system?s normal operation.

Lumen – A unit used to measure the amount of light available from a light source. A single lumen is equal to the amount of light produced by a single candle.

Lumens/Watt – A unit used to measure the efficacy of a light fixture. Lumens/watts measure the output of light per watt of power consumed.

M

Marginal Cost (Electric Utility) – The cost to a utility of providing another kilowatt-hour of electricity, despite current sunk costs.

Megawatt (MW) – A unit used to measure electricity, equal to 1,000 kW or one million watts.

Megawatt Hour – An amount of electrical energy usage equal to 1,000 kilowatt hours.

Meter – A device used for measuring individual electric consumption in a property.

Module – Another name for solar panel, referring to a grouping of solar photovoltaic cells that are connected together to form a single panel meant to gather heat from the sun and turn it into energy.

Municipal Electric Utility – A specific type of non-profit electric utility that is owned by a local jurisdiction or municipality.

N

Net Metering – A process that allows home solar panel users to sell extra energy they produce back to their local utility. The extra energy can also be rolled over to their next months? bill.

Net-Zero Energy – A term used to describe when a site produces as much energy that this specific site uses. Typically this refers to the production of renewable energy, such as solar or wind power.

Nuclear Energy – Power obtained by splitting or joining atoms to create a reaction and produce heat. The heat is used to make steam that runs turbine generators.

Nuclear Regulatory Commission (NRC) – An independent federal agency that ensures strict public health and safety standards are met during the creation and distribution of nuclear energy. The NRC regulates nuclear power plants throughout the United States and makes certain security measures are adhered to by any entity that possess and uses radioactive materials.

O

Obligation to Serve – An obligation of an electric utility to provide quality electric service to any customer who wants to use their service and is willing to pay the utility?s rate for service.

Off-Grid Electric – A term used to describe a stand-alone energy system that works separately from the main power grid.

Occupancy Sensor – A device that is used to sense movement in a room and control lights based on the presence of an individual within that space. These devices are meant to help save energy by automatically turning off lights when no one is in a room.

Outage – An outage, or a blackout, is a temporary interruption in electric service that impacts a large area and leaves that area without power for minutes or hours at a time.

P

Partial Load – When an electrical demand only uses a portion of the electricity available.

Passive Solar Energy – A process that uses a building?s architectural design and the sun to meet a building?s energy needs. Most passive solar energy strategies use materials, such as flooring materials that can store heat.

Passive Solar System – A solar heating or cooling system that collects solar heat but does not use any external mechanical power to move that collected heat.

Peak Demand – Peak Demand, also known as peak load, relates to the maximum amount of electricity demand during a specific time. The daily peak demand typically occurs on weekdays when the electric demand in the highest, while the peak demand for the year typically occurs in the summer.

Peak Load Power Plant – A plat or station that generates power and specifically works to create extra electricity to use during peak demand times.

Peaking Unit – A utility?s separate power generator that produces extra electricity for a service area during peak demand times.

Photovoltaic – An energy conversion method that transforms solar energy into electricity. Solar panels are typically called photovoltaic panels or photovoltaic cells.

Power Plant – A power generating station that generates and produces energy for a given service area or utility.

Power Purchase Agreement (PPA) – A contract between an energy generator, or the seller, and a party looked to purchase electricity, typically a utility or independent supplier. This contract defines the terms of this sale, including detailed information on pricing.

Price to Compare – This is a line item that appears on electricity bills from local utilities in deregulated markets. This price is used to be a benchmark for consumers so they can compare and see the rates for different energy plans in their area. This term is meant to help consumers determine if they could save money by switching suppliers.

Provider of Last Resort – This term is often included in utility contracts and it describes the legal obligation that electric utilities have to provide service to customers when that utility?s competitors have decided not to provide that individual with energy services.

Q

Qualifying Facility – A small power producer that generates electricity and has the right to sell its excess power. Typically, these facilities use renewable and alternative sources such as solar power or biomass. These facilities must meet federally regulated operating and efficiency standards.

R

Real-Time Pricing – When energy pricing changes according to the time of day. Electric utilities post these rates ahead of time so consumers can plan their energy usage accordingly.

Renewable Energy – Energy that comes from resources that are able to naturally renew themselves. For example sun, water or wind. Technology can use the power generated by these items, such as the power from flowing water, blowing wind or the rays from the sun and transform it into usable electricity.

Renewable Energy Certificates (REC) – These certificates, also known as Renewable Energy Credits, represent a single megawatt hour (mWh) of energy generated from a renewable resource. Consumers can offset the amount of fossil-fuel generated energy they use by purchasing a REC.

Retail Electric Provider (REP) – An REP is a company that sells electricity to customers in deregulated markets. These companies must be certified by their local Public Utility Commission in order to sell energy.

Reserve – An extra source of generated electricity that utilities create, beyond their highest demand level, to use in emergency situations.

S

Self-Generation – An electric generating facility that services a particular retail customer. Typically this facility is owned directly by the retail customer or an approved third-party. Many times large properties in rural areas will have self-generating facilities on their properties.

Solar Cell – A photovoltaic device that takes sunlight and converts it into electricity. Solar panels use multiple solar cells together to create enough electricity to power a building or home.

Solar Lease – An agreement between a homeowner and a solar panel company that is used to help finance the installation of these panels on a home. Typical solar leases range in length from 15-25 years and make solar energy more available to the general public, as there are no required upfront costs with getting solar panel installation.

Solar Panel – A panel that is placed outside a home or building that features dozens of solar cells. Solar panels use these sells to collect the sun?s rays and transform that light into usable electricity.

Solar Power Purchase Agreement – A financing solution for homeowners who want solar panel installation. This agreement allows the homeowner to have a system installed at little cost in exchange for an agreement to purchase power provided by the solar installation company.

Supply Charges – A portion of an electricity bill that covers the actual amount of energy consumed during the given billing period.

T

Teaser Rates – Special rates that are below standard market pricing. These rates are used to lure in new customers and typically go up dramatically after a few months.

Terms of Service (TOS) – A purchase contract between a customer and an energy supplier that details the specifics of the deal. The TOS covers fees, length of service and other important information that both parties have agreed upon.

Therm – A measurement of 100,000 British thermal units (Btus).

Time of Use Rates – Electricity pricing that is based on the estimated cost of energy during a particular time of the day. Typically there are three to four block times in every 24 hours period, classified as on-peak, mid-peak and off-peak times, with some markets also having super off-peak rates. Some utilities offer incentives to consumers who use less power during their high peak times during the day.

U

Usage – A measured amount of energy that an individual used during a specific billing cycle. Electricity bills measure usage in kWh. This is the part of the energy bill that customers have control over.

Utility – A term used to describe a company that generates and delivers electricity. There is a utility in charge of every service area in the United States. They are responsible for energy generation and delivery and in charge of power lines in their service area. Even customers who purchase an energy supply from a retail energy provider are still getting their electricity from their utility.

W

Warranty – A guarantee from a seller that promises that their electric product is what it is represented to be.

Watt – An electric power measuring unit that measures how much power something uses at a single point in time.

Weather Stripping – The process of putting specially designed insulating strips and seals around doors and windows to further insulate and property and prevent heating and cooling loss. This practice is typically used in homes to help conserve energy.

Y

?Your Rights as a Customer? Disclosure (YRAC) – A document that accompanies a new energy contract and details a person?s rights as an electric consumer. All electricity suppliers are required by law to provide their customers with this disclosure.

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