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ISBN 978-1941144374

ABOUT THE AUTHORS

Peter A. Vosbury

Peter A. Vosbury grew up in South Florida in the 1950s and early 60s. His first exposure to aviation was through his step-father, who was the Director of Personnel for Pan American World Airways. He spent time at the airport, watching airplanes take off and land, and was always asking questions about what made them fly and how all the parts and pieces worked. He always had an interest in technology, and enjoyed taking things apart, figuring out what made them work, and then putting them back together.

After graduating from high school, Peter had an opportunity to attend a liberal arts college in Winter Park, Florida. After one semester, he knew that was not the type of education he was looking for. He was interested in aviation and technology, and he learned about a school in Daytona Beach known as Embry-Riddle Aeronautical Institute (now University). He attended Embry-Riddle, graduating from the Airframe and Powerplant technical program.

After graduating from Embry-Riddle, he worked in General Aviation at an airport in Saint Petersburg, Florida, before joining the U.S. Navy in 1969. In the Navy he worked as an Aviation Machinist Mate Jet (ADJ), maintaining the powerplants on a squadron of airplanes known as the E-2 Hawkeye. He served on the aircraft carrier USS Forrestal, deploying to the Mediterranean four times between 1970 and 1973. When the squadron was not deployed, Pete had a chance to work in a propeller overhaul facility, and to have some flight engineer time in the C-130.

When Peter got out of the Navy in 1973, he went back to school, completing his graduate degree in education at the University of Central Florida. In 1976 he had an opportunity to become a member of the faculty at Embry-Riddle Aeronautical University, where he has been teaching ever since. He is a professor in the Aeronautical Science Department, where he teaches the Aircraft Systems course and the Gas Turbine Engines course. He has also taught math, physics, and aviation regulations at the University.

Peter is the author of a book on Aircraft Gas Turbine Powerplants, has written chapters on physics and weight and balance for an FAA published textbook, has published numerous magazine articles on aviation technical subjects, and wrote the answers and explanations study guide for the FAA written exams.

The success that Peter has had in the aviation industry can be credited primarily to three things. First and foremost is the love and support that his wife Linda has provided. Second is the work ethic and the desire to learn that his mother, Salley, instilled in him. Third is the kick start to his aviation education that Embry-Riddle provided, especially Professor Frank Moran, who mentored him when he was a student, and eventually hired him when he came back to be a member of the faculty.

William A. Kohlruss

William A. (Bill) Kohlruss started his aviation flying career by gaining his Private Pilot Certificate at Kent State University Airport in 1978. Bill, originally from Northeast Ohio, enlisted in the United States Navy after graduating from high school. After completing boot camp, Bill attended the Navy's Basic Propulsion and Engineering program and then went on to complete Machinist Mate Class "A" School in Great Lakes Illinois. Before joining the fleet, Bill was sent to Treasure Island California to learn hydraulics and electronics at the Navy's Underway Replenishment "STREAM" School. After nine months of schooling Bill was finally assigned to the U.S.S. Nitro AE 23, home ported in Rhode Island. Aboard the "Nitro", Bill made several naval cruises that took him half way around the world in both directions. In 1972/73, Bill completed a tour of duty in Vietnam.

After his four year enlistment, Bill returned to Ohio where he attended the United States Institute of Technology where he was certified as an Air Conditioning and Refrigeration Technician. It was while Bill was making a living working in a factory that he took up flying as a hobby. The freedom of flight was all it took to send Bill in a new career direction.

Deciding that flying was what he wanted to do, he set out for more education and flight training. Attending a Community College, a University, and flight schools, Bill acquired his FAA Airline Transport Pilot Certificate (type rating B-737), Certified Flight Instructor Certificate ASML-IA, Ground Instructor Certificate AI, and Airline Dispatcher Certificate along with two Associate Degrees, a Bachelors Degree, and a Master of Science Degree from Embry Riddle Aeronautical University.

Bill is currently a Professor at Embry Riddle Aeronautical University, where he teaches Aircraft Systems and Components and Crew Resource Management. He has also taught Aircraft Engines-Turbine, Flight Navigation and Airline Dispatch Operations along with several ground schools including Private, Commercial, Instrument and Multi-Engine. He is active with the Aviation Accreditation Board International where he chairs accreditation team visits to other Universities. He has also been the Editor of a professional journal, the "Journal of Aviation and Aerospace Education and Research".

Bill feels his success has been influenced by many, but three people stand out as his supporters and mentors. His wonderful wife of 28 years, Linda, has always been by his side to keep him on track. His cousin Danny Derreberry, took him up for his first "hands on" airplane ride. His Sister, Dianne Kohlruss Schubert (a teacher for 30 years), showed him that education was one of the keys to success, and that becoming a teacher can really make a difference in the lives of others.

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Out of Phase Condition

When two waveforms go through their maximum and minimum points at different times, a phase difference will exist between the two. In this case, the two waveforms are said to be out of phase with each other. The terms lead and lag are often used to describe the phase difference between waveforms. The waveform that reaches its maximum or minimum value first is said to lead the other waveform. Figure 3-11B shows this relationship. Voltage source one starts to rise at the 0° position and voltage source two starts to rise at the 90° position. Because voltage source one begins its rise earlier in time (90°) in relation to the second voltage source, it is said to be leading the second source. On the other hand, the second source is said to be lagging the first source. When a waveform is said to be leading or lagging, the difference in degrees is usually stated. If the two waveforms differ by 360°, they are said to be in phase with each other. If there is a 180° difference between the two signals, then they are still out of phase even though they are both reaching their minimum and maximum values at the same time. (Figure 3-11)

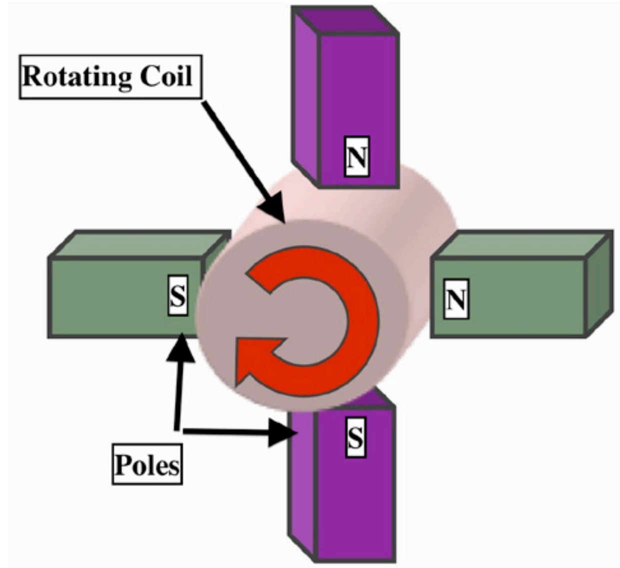

Figure 3-10. Four pole generator.

POWER IN AC CIRCUITS

In a direct current (DC) electrical system, power is the product of the voltage and current and is measured in watts. In an alternating current (AC) electrical system, the current is not necessarily in phase with the voltage, meaning the voltage and current are not peaking at the same time. In this case, the product of the peak voltage and amps is referred to as apparent power, and is measured in volt amps.

TRUE POWER DEFINED

The power dissipated in the resistance of a circuit, or the power actually used in the circuit. In an AC circuit, a voltmeter indicates the effective voltage and an ammeter indicates the effective current. The product of these two readings is called the apparent power.

APPARENT POWER DEFINED

That power apparently available for use in an AC circuit containing a reactive component. It is the product of effective voltage times the effective current, expressed in volt-amperes. It must be multiplied by the power factor to obtain the true power available.

POWER FACTOR

"Power factor" is a term used to indicate the amount of the current that is in phase with the voltage, and it may be found as the ratio between the true power and the apparent power. If the power factor is 0.5, only 50% of the current is in phase with the voltage. If all of the current is in phase with the voltage, as it is in a circuit having no opposition other than resistance, the power factor will be 1.0.

Only when the AC circuit is made up of pure resistance is the apparent power equal to the true power. When there is

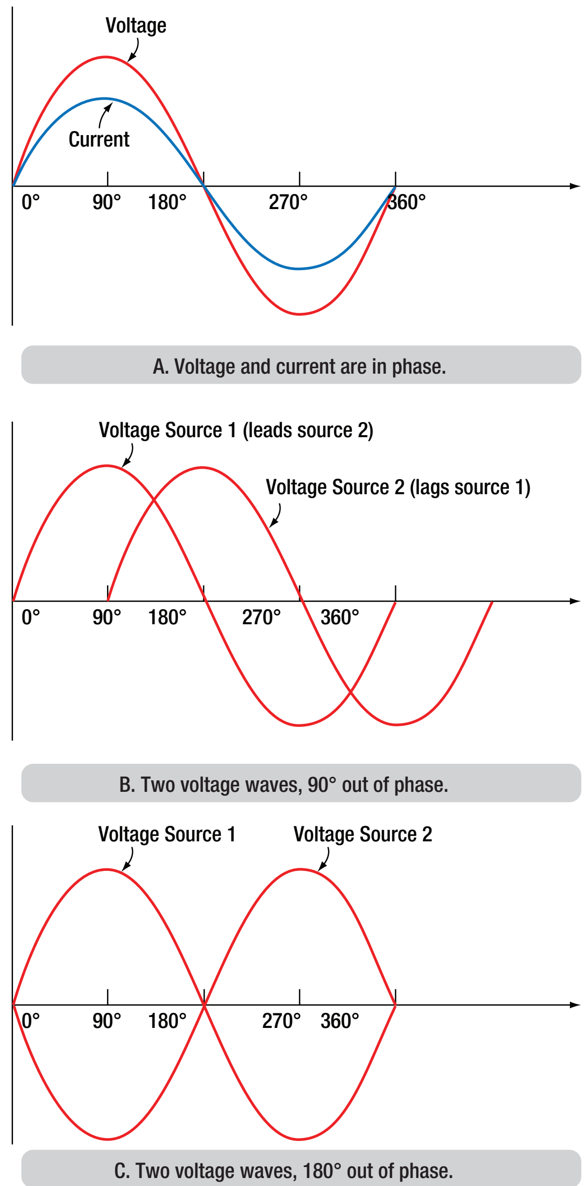

Figure 3-11. In phase and out of phase conditions.

capacitance or inductance in the circuit, the current and voltage are not exactly in phase, and the true power is less than the apparent power. The true power is obtained by a wattmeter reading. The ratio of the true power to the apparent power is called the power factor and is usually expressed in percent. In equation form, the relationship is:

$$\text{Power Factor (PF)} = \frac{100 \times \text{Watts (True Power)}}{\text{Volts} \times \text{Amperes (Apparent Power)}}$$

Example: A 220-volt AC motor takes 50 amperes from the line, but a wattmeter in the line shows that only 9,350 watts are being used by the motor. What are the apparent power and the power factor?

Solution:
Apparent power = Volts × Amperes
Apparent power = 220 × 50 = 11,000 watts or volt-amperes.
(PF) = (Watts (True Power) × 100) ÷ VA (Apparent Power)
(PF) = 9,350 × 100 ÷ 11,000
(PF) = 85, or 85%

VALUES OF ALTERNATING CURRENT

There are three values of alternating current, which are: instantaneous, peak, and effective (root mean square, RMS).

INSTANTANEOUS VALUE

An instantaneous value of voltage or current is the induced voltage or current flowing at any instant during a cycle. The sine wave represents a series of these values. The instantaneous value of the voltage varies from zero at 0° to maximum at 90°, back to zero at 180°, to maximum in the opposite direction at 270°, and to zero again at 360°. Any point on the sine wave is considered the instantaneous value of voltage.

PEAK VALUE

The peak value is the largest instantaneous value. The largest single positive value occurs when the sine wave of voltage is at 90°, and the largest single negative value occurs when it is at 270°. Maximum value is 1.41 times the effective value. These are called peak values.

EFFECTIVE VALUE

The effective value is also known as the RMS value or root mean square, which refers to the mathematical process by which the value is derived. Most AC voltmeters will display the effective or RMS value when used. The effective value is less than the maximum value, being equal to .707 times the maximum value. (Figure 3-12)

The effective value of a sine wave is actually a measure of the heating effect of the sine wave. Figure 3-13 illustrates what happens when a resistor is connected across an AC voltage source. In illustration A, a certain amount of heat is generated by the power in the resistor. Illustration B shows the same resistor now inserted into a DC voltage source. The value of the DC voltage source can now be adjusted so that the resistor dissipates the same amount of heat as it did when it was in the AC circuit. The RMS or effective value of a sine wave is equal to the DC voltage that produces the same amount of heat as the sinusoidal voltage.

INDUCTANCE

CHARACTERISTICS OF INDUCTANCE

When current flows in a conductor, a magnetic field surrounds it and the strength of the field is determined by the amount of current flow. The direction of the lines of flux around the conductor may be found by the left-hand rule for generators, which states that if the conductor is held in the left hand so that the thumb points in the direction of electron flow (from negative to positive), the fingers will encircle the conductor in the direction of the lines of flux. This is shown in Figure 3-14.

As the amount of current flow changes, the magnetic field expands or contracts. As it does, the flux cuts across the conductor and induces a voltage into it. According to Lenz's law, the voltage that is induced into the conductor is of such a polarity that it opposes the change that caused it. For example,

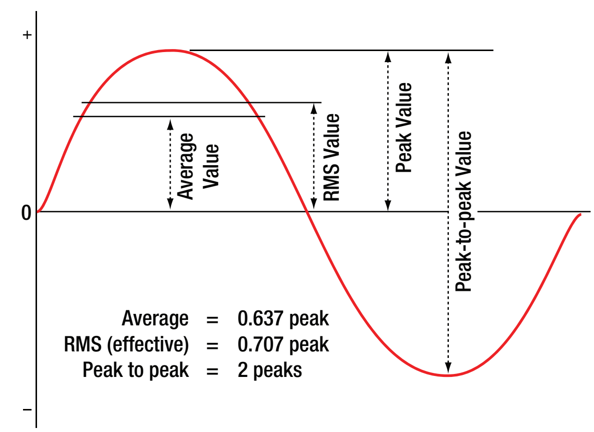

Figure 3-12. Values of AC.

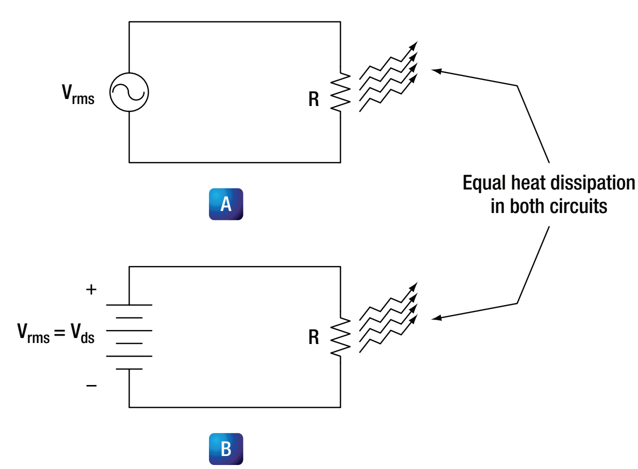

Figure 3-13. Sine wave effective value.

as the voltage begins to rise and the current increases, the expanding lines of flux cut across the conductor and induce a voltage into it that opposes, or slows the rise.

When the current flow in a conductor is constant, lines of flux surround it, but since there is no change in the amount of current, the lines of flux are not moving and there is no induced voltage. When the current decreases, the lines of flux cut across the conductor as they collapse, and induce a voltage that opposes the decrease.

When a conductor carries alternating current, both the amount and the direction of the current continually change, so an opposing voltage is constantly induced into the conductor. This induced voltage acts as an opposition to the flow of current.

FACTORS AFFECTING INDUCTANCE

Inductance opposes a change in current by the generation of an opposing voltage, and all conductors have the characteristic of inductance, since they all generate opposing voltage any time the current flowing in them changes.

The amount of inductance is increased by anything that concentrates the lines of flux or causes more of the flux to cut across the conductor. If the conductor is a coil, the lines of flux surrounding any one of the turns cut not only across the conductor itself, but also across each of its turns, and generates a greater induced current to oppose the source current.

If a soft iron core is inserted into the coil, it will further concentrate the lines of flux and cause a still higher induced current, which allows less source current to flow.

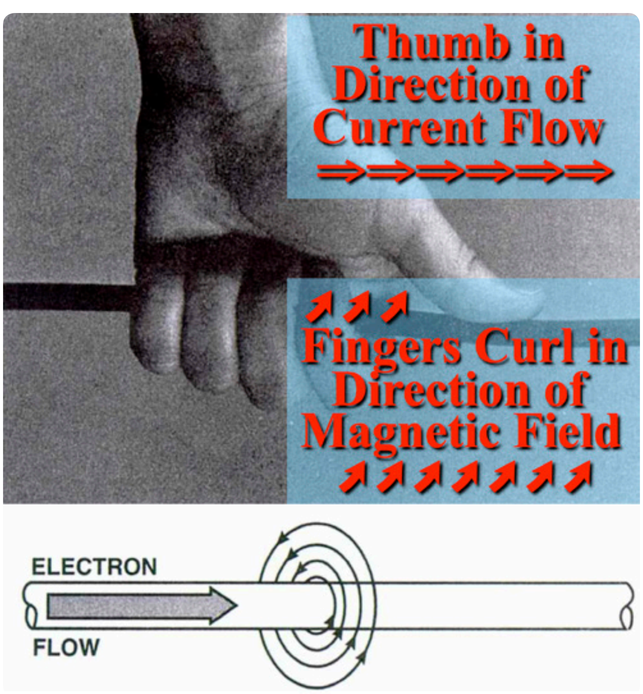

Figure 3-14. Current carrying wire flux lines.

MUTUAL INDUCTANCE

When alternating current (AC) flows in a conductor, the changing lines of flux radiate out and cut across any other conductor that is nearby. As they cut across a conductor, they generate a voltage in it even though there is no electrical connection between the two. This voltage is generated by what is known as electromagnetic induction (mutual inductance), and it is the operating principle for step-up and step-down transformers.

Figure 3-15 shows two wires positioned side by side, with the larger of the two being powered by AC. When the current in the wire changes direction every 1/2 cycle (alternation), a magnetic field (flux lines) expands and then collapses around the wire. The expanding and collapsing flux lines induce voltage in the smaller wire and create a flow of current, and this process is known as mutual inductance.

Transformers

Transformers are an excellent example of utilizing mutual inductance to modify the voltage and the current in an electrical circuit. They consist of two coils of wire, a primary and a secondary, wound around a common core of soft iron. The two coils of wire are not connected electrically.

Alternating current or pulsating direct current provides the input to the primary side of the transformer. The secondary windings in the transformer provide the output voltage and current to the electrical circuit. If there are more turns of wire in the secondary coil of the transformer, the output voltage will be increased and the output current will be decreased, and it will be known as a step-up transformer. If there are fewer turns of wire in the secondary coil, it will be known as a step-down transformer.

In our every day lives transformers are all around us, many times without us even realizing it. Electric power companies use transformers to step up the voltage at the generating station, to tens of thousands of volts, before they send it out to our houses. When the electricity arrives at our houses, step-down transformers are used to provide the 120 volts AC that we need for our lights and appliances. The big gray cylinder at the top of the power pole is a step-down transformer. The charger we plug in for our cell phone or laptop computer contains a step-down transformer. A transformer does not change the output power. The best it can do, if it is 100% efficient, is to have the

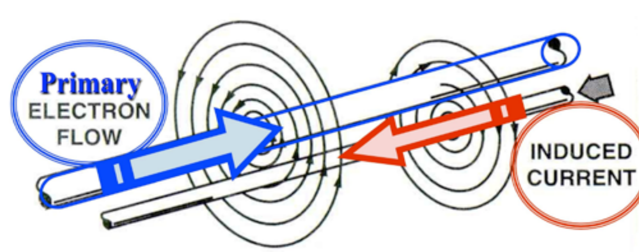

Figure 3-15. Mutual inductance.

output power be equal to the input power. Because power is equal to the product of volts and amps, if the volts are being stepped up, the amps must be stepped down.

Figure 3-16 shows a step-down and a step-up transformer. In view "A", the secondary has 1/5 as many turns as the primary, so the output voltage would be 1/5 as much as the input voltage (step-down). In view "B", the secondary has 4 times more turns than the primary, so the output voltage would be 4 times greater than the input voltage (step-up).

Example:

In Figure 3-16A, the input voltage is 200 VAC and the input current flow is 5 amps. What are the output voltage and the output current?

Solution:

$$\text{Input Volts} \times \frac{\text{Output Turns}}{\text{Input Turns}} = \text{Output Volts}$$

$$200 \times \frac{2}{10} = \text{Output Volts}$$

$$\text{Output Volts} = 40 \text{ VAC}$$

$$\text{Input Amps} \times \frac{\text{Input Turns}}{\text{Output Turns}} = \text{Output Amps}$$

$$5 \times \frac{10}{2} = \text{Output Amps}$$

$$\text{Output Amps} = 25$$

Assuming the transformer is 100% efficient, the input power would be 1,000 volt-amps and the output power would also be 1,000 volt-amps.

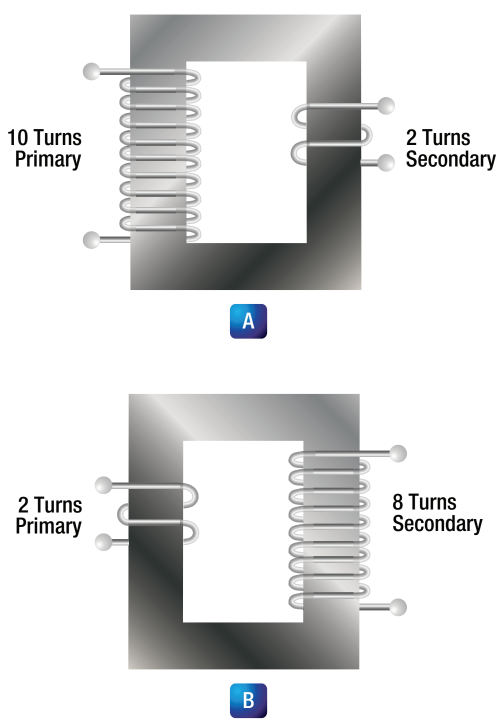

Figure 3-16. Step-Down and Step-up transformers.

CAPACITANCE

Electrical energy can be stored in a number of different ways. In the previously discussed concept of inductance, electrical energy is stored in the magnetic field surrounding a current carrying coil of wire. In a battery, electrical energy is stored in the potential chemical reaction within the battery's cells. In a capacitor, sometimes called a condenser, electrical energy is stored in the electrostatic fields that exist between two conductors that are separated by an insulator, known as the dielectric.

In aircraft, capacitors have a variety of uses, to include powering anti-collision strobe lights, controlling the input power to an AC motor, and preventing arcing of the points inside a piston engine magneto (ignition device). Figure 3-17 shows a strobe light in the form of a neon bulb, which is powered by the capacitor when the switch is in position "B". When the switch is in position "A" the capacitor is charged by the battery.

Figure 3-18 depicts a capacitor, where there are two flat metal plates facing each other, separated by an insulator known as the dielectric. One of the plates is connected to the positive terminal of the battery and the other to the negative terminal. When the switch is closed, electrons will be drawn from the plate attached to the positive terminal and will flow to the plate attached to the negative, and the capacitor will be considered charged. There will be no flow across the dielectric. During the brief period of time that the capacitor is charging, the ammeter will show the current flow. When the switch is opened, the capacitor will remain charged until it is connected to an electrical circuit that will allow the electrons to flow.

FACTORS AFFECTING CAPACITANCE

The amount of electrical energy a capacitor can store is determined by three variables: the area of the plates, the separation between the plates, and the type of material used for the dielectric.

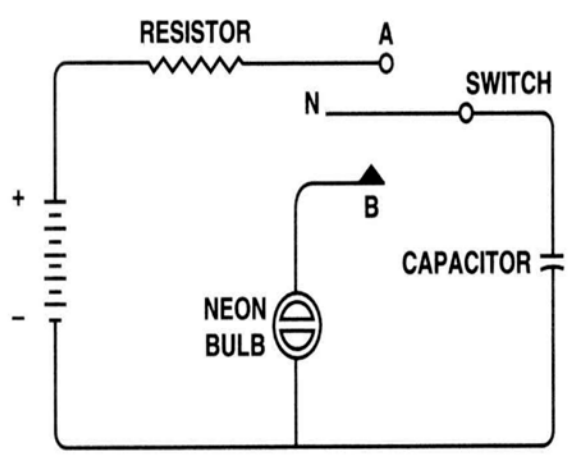

Figure 3-17. Capacitor powered strobe light.