NOTE: This handout is very comprehensive and an excellent source of info, but the class is "101" for a reason – it is for the non-technical person. If you want more details, there's ample Q&A time after class.

Emergency Backup Power – ***Generators, UPS, Surge Protectors, etc***.
by Robert J. "Bob" Schwartz

For those of us who live in Houston or near the coast, Hurricane IKE was a wakeup call. Many of us couldn't recall a previous hurricane hit or how long we had been without power. CenterPoint has been a reliable source of power and we couldn't imagine being without power for a week or two or more.

After a number of powerless days, some of us were lucky enough to acquire a generator. Others have vowed "Never again! We are going to get a backup system!" If you fall in this category, what should you consider? (In the discussion to follow, we will NOT be dealing with any **mission-critical applications** in which no loss of power, even for a moment, can be tolerated. In fact, you can expect an outage from 10 to 30 seconds or so for a fully automated system, up to an hour or more for a completely manual system.)

Kinds of losses that justify a generator:

(1) Economic loss – loss of refrigerated food – How much are the contents of your refrigerator and its freezer section worth? If you have a business, not only the loss of refrigerated items but the ability to conduct your business for days, pump gas for a convenience store, maintain communication to be able to continue on-line transactions, etc.
(2) Convenience – lighting – cooking – air conditioning – fans – washing and drying clothes – washing and drying yourself - powering your computer.

If you are seriously considering an emergency backup generator, I suggest that you follow this article through to the end, *even if it puts you to sleep a few times*. It will give you a flavor for the various issues that you have to consider. Then, if you decide upon an installation that will use some or all of the house wiring, you will be better prepared to discuss what will be needed with your licensed electrician – and you will need one.

First consideration is to decide: what you (1) MUST HAVE, (2) what you would LIKE TO HAVE, and (3) what would be NICE TO HAVE.

These will determine the generator **size** that you will need and the **mode of operation**.

If you are in a circumstance where you experience periodic losses of power and you can't tolerate an extended loss of power, then you will probably have to plan on an *automatic* system.

If power losses are rare and you can tolerate a loss of power for an hour or so, you may be able to get by with a *manual* system that has to be hauled out of your garage or storage shed, fueled, hooked up, and started.

"Loads" that your generator will have to supply: You can look on the Internet for items and appliances and their *START* and *RUN* loads under categories like **emergency power, emergency generators, portable generators**, etc. See also, included Appendix.

Lights, toasters, irons, microwave ovens, for example, have RUN ratings only. Others, with **motors,** such as refrigerators, freezers, air conditioners, washers, pumps, compressors, etc. *have both **START** and **RUN*** ratings. It takes extra burst of power to start a motor and bring it up to run speed, and the generator will have to supply this extra power until the motor reaches its normal run speed. Most electronics have a relatively constant power requirement although computers and monitors have an almost instantaneous peak start current. Motors take several seconds to come up to speed. You just have to hope that all your motors don't start at the same time.

To create your RUN list, add the loads of the MUST have, the LIKE to have, and the NICE to have items that you want to include to the above. I would suggest adding 25% to the **RUN total** after figuring the above to cover items that might have been overlooked and to provide a cushion. Then look at all the items that have a START value. Pick the worst one. The **RUN total** will dictate the **minimum RUN rating** for the generator. When you **add the START** value to the **RUN value**, this will **dictate the SURGE rating** (initial required electricity). Make sure you understand the "Start" rating from these various sources. They are not done the same way. Some represent the Start value to add to the Run value, some total both, some include a factor "times the run value".

At this point, you should have figures to determine the ***needed generating capacity***. Generators are available from less than 1000 watts to over 200,000 watts, to cover whatever you need and can afford.

You are now at START. You are **not** ready to pass GO. There are other things to consider.

Choice of fuel. Most small portable generators are fueled by gasoline. Most are rated for operating time at *half load*. One needs to make sure that it has enough capacity to run for 10 to 12 hours on a full tank. Natural gas, propane and diesel fuels are also available.

For those of us who sat in line for an hour or more to get five gallons of gas, the possibility of something other than gasoline is worth considering. Fueling by natural gas may dictate a somewhat more fixed installation. Some tri-fuel generators have slightly less generating capacity when running on propane or natural gas, than when fueled with gasoline. Use the internet to find firms that offer devices that can convert the gasoline powered generator to one that will also or alternatively run on propane or natural gas.

Starting: Next might be how to start it **– manual or electric start**. Manual is the simplest and least expensive. Electric is the easiest, just push a button, and is **required for an automatic system.**

Maintenance Issues: Electric start generators have a special demanding maintenance issue: they have a battery which must be **periodically charged/recharged** and the **generator must be periodically restarted and run for a short time** to recharge the battery and make sure that the battery hasn't deteriorated to the point where it won't restart the generator. Batteries do not last forever. They deteriorate. Gasoline powered generators need a "stabilizer" added to the fuel to prevent gum and varnish build up. And, all require that the oil be changed and the air filters be cleaned.

Noise: How well muffled is the generator? If power is out in the summer and the generators of you and your neighbors can not handle your air conditioners, windows will be open. A noisy generator may have to be turned off at night because of the noise – no fans, no window A/C, etc. Most generators for **standby service** are equipped with very quiet mufflers. Quieter mufflers for portable units may not be readily available. One issue in selecting an alternative muffler is whether it may create enough back pressure to reduce generator output or damage the engine (check with the manufacturer on this point).

Power Quality. Small generators cannot compete with Center Point on power quality. They do not have the **voltage stability** of 117 Volts +/- a few volts, the **frequency stability** of 60 hertz (cycles) – ability to run clocks accurately for years - and **low waveform distortion** – important for electronic devices. We'll touch on these issues later

Output voltages: Most of these generators **deliver 240 Volts AC and 120 Volts AC, single phase,** and they have separate sockets for each. What does all this mean? Essentially, these generators each have two generating coils, connected in series. Each coil generates 120 volts. Connected in series, the 2 voltages add up to deliver 240 volts. The connection where the two coils are joined, are connected to the frame of the generator and are referred to as the **"neutral/ground"** connection. The ends of the coils are referred to as the **"hot" terminals**. One will be going positive as the other is going negative. Thus, the two "hot" terminals, between them, will produce 220 – 240 Volts, while between each "hot" terminal and the "neutral" will produce 120 Volts. This **"neutral/ground"** connection is VERY important and we will deal with it shortly. It is critical from a safety perspective that it be connected properly. It **must be grounded**.

On the **smaller generators**, there may be only standard 115 volt three-pin grounded outlets connected to each leg of the 240 volt output of the generator -while larger ones will also have one, or more, 4 contact sockets to handle the 240 Volt service.

The 115 Volt standard outlets can handle 15 – 20 amperes each, so a generator that has an output greater than 15 – 20 amperes will have several such outlets. Generators with output capabilities greater than 20 amperes will be equipped with 4 contact sockets with ratings of 20, 30, 50, or 60 amperes, depending on generator capacity. Each such socket is unique and will accept only its proper mating plug with the appropriate rated current carrying capacity. Each type is different (L14-20, L14-30, L14-50 type sockets and mating plugs are common).

The total of all the current loads on ALL the sockets, taken together, must be within the capacity of the generator. Else, the generator will object and the overload breaker will trip, if it has one.

Alternating Current (AC) has a voltage and current that varies continuously from zero to a maximum positive value, back to zero, to a maximum negative value, and then back to zero. This variation is called a cycle. In the U.S., this variation (cycle) occurs 60 times a second (50 in Europe) and is referred to as 60 *hertz*, where a hertz is a cycle per second.

All major power systems, such as Center Point, use rotating machinery (big versions of portable generators) to generate electricity for our power grid. This power is three-phase. That's why when you look up at power poles, you generally see groups of three wires. Normally only one phase (between any two of the three wires) is delivered to a residence. For industrial applications 3 phases are normally delivered. Big motors need three-phase. For the purpose of this handout, there is no additional discussion of three-phase power.

The one (single) phase delivered most commonly to residences is 240 volts, with a center tapped neutral, just like the description for the generator above. Each "leg" (hot wire) is 120 volts from the neutral and 240 volts between the two "legs". That's why **the "drop" from the power pole frequently has two insulated conductors and one bare or white insulated (neutral) conductor** to bring power to your residence.

As **power is brought in**, the two "hot" legs go through your meter and thence to your circuit breaker panel. There are three, of what are called, **bus bars** in this panel. Each "hot" leg goes to one of the "hot" bus bars, and the neutral goes to its bar. Various circuit breakers are connected between the "hot" bus bars and the circuits in your house or office.

Circuit breakers for 120 Volt service connect to **one** or to the other **"hot" bus bar**. Circuit breakers for 240 volt service have two sections with a common handle. One section connects to one of the "hot" busses. The other section connects to the other "hot" bus. Single circuits are distributed some on one leg, some on the other, chosen to balance the loads, as best possible, thus to be about the same total load on each leg.

Each house circuit starts from the output of its circuit breaker via a black or red insulated wire and returns via a white wire to the neutral bus. The neutral bus is grounded at the power pole and **also** at the circuit breaker panel by a **ground rod** (required by the electrical code). Also connected to this grounded neutral bus is a ground bus which is connected green insulated wires. While the green and white wires are connected together at the panel, they serve different purposes. The white wire carries circuit current. The green wire is connected to the outside or **case** or frame of the device you plug into the outlet. Its purpose is safety. Because one carries current and the other does not, there can be a small voltage difference between them at the outlet.

The **ground bus** of your home will have to be located and a means provided so the neutral of the generator can be connected to it. **This is critical!**

Why all the above nitty-gritty? So we can discuss how to connect the generator to your house.

We will continue the discussion based upon a residential system; however, an office or business system can use the same philosophy.

We need to **examine the circuit breaker panel** to determine how it is wired. Some have a main breaker that is located between the wires from the meter and the "hot" busses. Turning this OFF kills everything. Others may have the hot busses split and the main breaker connected across the split. This lets some heavy loads, often 240 Volt loads such as the circuit breakers for air conditioners, ovens, and clothes dryers, be connected ahead of the main breaker so the main breaker doesn't have to have as large a current capability. Instead, the heavy loads are protected by their own breakers, and the "Main" breaker handles all the lighting and local outlets. Flipping OFF the MAIN breaker only shuts OFF some of the circuits, not ALL. You may need an electrician to determine all this for you.

Why is this important? For a permanently wired automatic system, we may want only part of the various circuits in the house to be powered. We may also need some of the circuits ahead of "main" breaker" to be emergency powered. The same holds for a manual system.

Extension Cords or Using House Wiring: Wires have resistance. When one passes current through a conductor, the more current or the more resistance, the more voltage drop there is. Common wire sizes for extension cords are 16, 14 and 12 gauge, with 16 having the smallest wire and the highest resistance, 12 gauge the larger. Why care? If the generator provides a terminal voltage of 120 volts, and 10 volts is lost in the extension cord, only 110 volts is available to operate your microwave. The idea is to *limit the voltage loss under load to less than five to 10 volts*. Also, the current flowing through the wire causes heating and we don't want to damage the insulation of your extension cord or start a fire.

Extension cord specifications, such as these below may be found in various catalogs.

Wire Gage	Length (ft.)	Maximum Current (amperes)
16	25	13
16	100	10
14	25	15
14	50	15
14	100	13
12	25	20
12	50	20
12	100	15

Common generator sizes and their output current capability:

Generator size (watts)	Current (@120 volts)	Current (@240 volts) Leg 1	Leg 2
3000	25	12.5	12.5
4000	33.3	16.7	16.7
5000	41.7	20.8	20.8
5500	45.8	22.9	22.9
6000	50	25	25
7500	62.5	31.3	31.3
8000	66.7	33.3	33.3
10000	83.4	41.7	41.7
15000	125	62.5	62.5

How to hook it up? Do you want a **temporary** or a **permanent installation**? Can you live with a collection of extension cords? Can you pass them from outside to inside without damaging the cords? Letting bugs in? Are you afraid of tripping over them? Can they reach all the items that you want to power? Or do you want to power up all or part of your house or office and use the built-in wiring? (And also be able to select items that will NOT be powered by the generator.)

Temporary versus permanent wiring. (manual versus automatic).

In any case involving powering house wiring with an emergency generator, **you MUST employ a transfer switch or its equivalent (electrical code requirement).** This requirement is to prevent **back feeding** – a circumstance where your generator would attempt to feed power back to the lines that normally supply power TO you. **BEFORE** your generator can be connected to your house circuits, **the connection between the house wiring and the lines normally supplying power to your home must be completely broken!** This is not a "nice" thing to do, it is not an "option", it is **MANDATORY!** Besides, your generator won't like back feeding. It will be like putting a dead short circuit on it. In other words, your generator may have the capacity to power your house circuits but it sure won't be able to supply the power grid. **This process has some very critical implications. If you don't know what you are doing, get someone who does! You could be responsible for killing someone and it might not be you!**

…..continued on the next page.

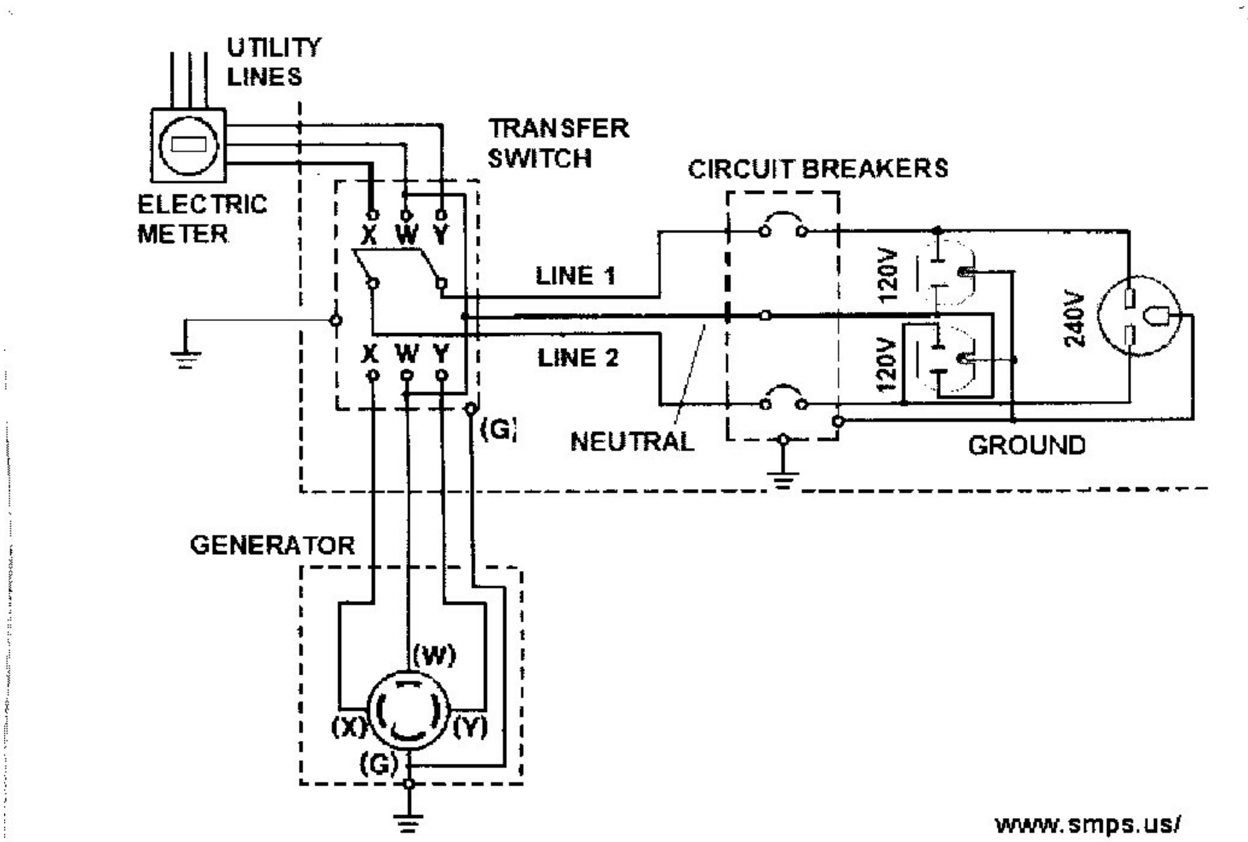

Figure 1

(This figure from the web site www.smps.us/, an excellent source.)

What is shown here is that power from the utility is brought into the residence through the meter. The meter output is brought to one set of terminals of the transfer switch. The generator output is brought to another set of terminals of the transfer switch. As illustrated, a DPDT (double pole double throw) switch selects which power source is to be used. The output (two hot leads from the DPDT switch) are routed to the circuit breaker panel OR to a set of transfer switch controlled branch circuit breakers.

A **transfer switch** must employ a Break-before-Make switch function. This **disconnects** from one source **before** connecting to another. This is the required type so that **line power** and **generator power** cannot be connected together, even for a moment.

Transfer Switches: These are the switches installed between power from the power line and power from the generator, and are used to select which source will power the house circuits. They are created in a variety of forms: (1) a single **double pole double throw** configuration to switch all of the house loads from **line power** to **generator power** in one step, and (2) are also available with switching for **4, 6, 8, 10, 12, 16, or more separate circuits** so as to select only certain house circuits to be powered by the generator. Each of these **multi-circuit transfer switches** may have limits of 15 to 20 amperes per separate circuit. Only a few can be found with greater capacities. Most are provided with a 10 ft. cable from the generator, so the generator may have to be located close to your circuit breaker panel.

Even with the above, there is one other consideration. **Most generators do not start well under load.** This means the generator should be started and allowed to come up to stable speed before connecting the load to them. This means there should be a **time delay** between when the generator starts and when the load is connected. Somewhere in the order of **10 to 30 seconds** may be appropriate. This is particularly important for automatic systems. For manual systems, the time it takes to start the generator with nothing plugged in, and grab the plug(s) and plug them in will usually be enough delay.

For automated operation, the **transfer switches may provide several functions**:

(1) Detects failure of power from the power line.
(2) Starts the generator
(3) Waits (time delay) until the generator comes up to stable speed and voltage
(4) Transfers the power source connection. Disconnects COMPLETELY from LINE POWER before connecting to GENERATOR POWER – VERY IMPORTANT!
(5) Detects when line power returns
(6) More sophisticated ones wait for a short time to make sure line power is stable
(7) Transfers house load to back to line power
(8) Shuts down the generator

Some of these switches can be very smart and somewhat expensive.

Generators designed for **standby service** are typically powered by natural gas, run very quietly, have clocks to automatically start and run for a short time every week to test its operation and to keep the start battery charged and, of course, are designed for permanent installation.

Let's go back to **power quality**. The nominal frequency for power in the U.S. is 60 hertz. The generators we are talking about use a governor to regulate the speed, usually at 3600 rpm. When a load is switched on, the generator's mechanical load on the engine is increased, so it slows down. Then the speed regulator senses the slow down, opens the throttle to speed up and regain 3600 rpm. Depending on the design and how well it is damped, it may over-speed a little, then slow down, speed up, etc. until stable 3600 rpm is achieved. When, a load is removed, the reverse process occurs. Both the speed (line frequency) and output voltage are regulated. If a load is added (within the capacity of the generator), the voltage drops a bit until the voltage regulator corrects the output voltage. So, keep in mind that the output voltage and frequency do vary.

So, who cares? Depending on the generator design and the loads put on it, the output voltage can vary substantially. This can put a lot of stress on items connected to it. Many items will weather this storm without damage, but some won't.

Protect your computer, monitor, and ancillary equipment at least by a **surge suppressor**. If the 10 second or more transfer time becomes an issue, a **UPS (uninterruptible power supply)** with a sufficient run time capacity for the **computer** and **monitor** long enough to bridge the transfer time, may be justified. In any case, if power failures are frequent, employing a UPS to provide an orderly shut-down will prevent data loss and corruption. A UPS with a USB (universal serial bus) or serial port cable to the computer to initiate an automatic orderly shut-down will be required.

Also relating to **power quality** is the waveform provided or the amount of **harmonic distortion** of the waveform. Line power provided by Center Point or one of its competitors is essentially pure sinewave.

Thus, there is a tightly controlled relation between “rms” (root mean square) and “peak” values of the supplied waveform. If the waveform of the auxiliary generator has significant waveform distortion/ harmonic distortion, it is possible for the generated waveform to have higher peak voltages than would be experienced with the pure sine-wave of normal line power. Some electronic equipment may not endure this well. Surge suppressors should be used for TV’s, stereos, iPods, Xboxes, etc.

Now let’s address the **engines** used on these generators. It’s bad enough that line power is not reliable enough that you have to go out and invest in an auxiliary generator. What if your generator was not reliable such as: hard to start, hard to keep running, does not run stably? Accordingly, it is recommended that you limit your purchase to a generator powered by a well-known engine brand such as: **Briggs and Stratton, Honda, Onan, and Kohler**. **Guardian by Generac** is well-known for producing a variety of generators for automatic standby service. This is not to suggest that other brands may not work well, but the above mentioned brands have a long track record. Don’t let **misrepresentation** or **cheap** fool you.

Physical Security: You have made a major investment in this generator and its connection. You want to make sure it is available to YOU when it is needed. Generators become prime targets for thieves when there are extensive power outages. Make sure that where you store or install the generator, it is secure and thief resistant.

In conclusion, let us summarize:

(1) Determine the load requirements, both the RUN and SURGE ratings are needed
(2) Determine if you will use extension cords, or use all or part of the house wiring
(3) If house wiring is decided upon, what kind of a transfer switch will be needed
(4) If house wiring is decided upon, determine what changes to the house wiring will be needed
(5) Determine the kind of fuel to be used –gasoline, natural gas, propane, diesel
(6) Select the generator
(7) Determine where it will be kept and/or where it will be installed-convenience and security
(8) Buy and install it
(9) Buy and install surge suppressors and UPS for your electronic equipment
(10) Test your system - - -You have now completed the course!

Appendix 1
COMPILATION OF **TYPICAL** ELECTRIC APPLIANCE POWER REQUIREMENTS

ITEM	RUN(watts)	START(add’l watts)	INFO SOURCE
Incandescent Light bulb:			
100 watt	100	0	nameplate
60	60	0	nameplate
CFL (coiled fluorescent lite)			
100 watt equivalent lite output	26	0	nameplate
60 watt equivalent lite output	13	0	nameplate
coffee maker	1000	0	(2)
dish washer (cool dry)	216	324	(4)
electric range 8” element (small)	2100	0	(2)
electric range (large	2400	0	(5)

microwave oven 800 watt	1400	0	nameplate
refrigerator/freezer	700	2200	(2)
toaster	850	0	nameplate
waffle iron	1200	0	(3)
hot plate	1200	0	(3)
frypan	1200	0	(3)
iron	1000	0	(3)
clothes dryer (electric)	5400	1350	(4)
hair dryer	600-1400	600-1400	(5)
Garage Door Opener – ½ HP	875	2350	(2)
Window Air Cond'r 10,000 BTU	1200	3600	(2)
Central Air Cond'r 2 ton	3800	11400	(9)
Central Air Cond'r 5 ton	9200	27600 (est.@3x)	(8)
Stereo Receiver	450	0	(2)
Color TV 27"	500	0	(2)
Flat screen TV (46")	190	0	(4)
Desktop Computer w/17" Monitor	300	0	(1)
Laptop Computer	50-75	0	(3)
Laptop computer	200-250	0	(4)
Inkjet printer	60-75	0	(3)

Uninterruptible Power Supply (UPS)1200VA 0 see name plate
(Power Sentry –Output 600VA/300W)

Run times for UPS rated 500 VA/300watts Load =	50 watts	100watts	200watts	300 watts
source of this data: (6)	57 min	23 min	7 min	2 min

Info Sources

(1) My Personal Measurements
(2) Troy-Bilt 5500 watt Generator Instruction Book

From Internet under category of "**appliance power requirements**": (see for more detailed data)

(3) www.donrowe.com/inverters/usage_chart.html
(4) www.hondapowerequipment.com/products/generators//content.aspx?asset=gg wattage
(5) www.generlink.com/appliance_guide.cfm
(6) www.geocities.com/dtmcbride/home_garden/power.html
(7) www.absak.com/library/power-consumption-table
(8) www.oksolar.com/technical/consumption.html
(9) 2008 Generator Buying Guide (Lowe's Inc.)

Robert J. "Bob" Schwartz is a HAL-PC member, graduated from Rice with a BSEE and an MSEE back before integrated circuits were invented, somewhat retired, 14 patents, technical writer, active in civic affairs – President, Brays Bayou Association (interested in reducing the risk of flooding); Vice-President, Marilyn Estates Association; and Corresponding Secretary, Willow Waterhole Greenspace Conservancy. He may be contacted at **bobx@hal-pc.org**.