Brief Summary – Non-conventional energy systems are roughly classified into four types of rotating energy systems and five types of stationary energy systems. Guidelines and tips are provided for measuring their performance, efficiency, etc.

Engineering Non-Conventional Energy Systems

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Abstract

Non-conventional energy systems encompass the production, transmission, and conversion of all forms of energy derived from sources which are generaily ignored by, or only speculated about in conventional scientific journals and research laboratories. Emphasis in this paper is on recent generation technology of the Bedini/Newman/Mueller/Watson type (see 1984 Tesla Centennial Symposium). All researchers desire to see their inventions enhance or replace conventional systems. The ultimate test of an invention's viability, given current economic realities, is whether it outperforms currently available devices (or will do so in the near future given reasonable time and funding) based on efficiency, weight, cost, complexity, etc. Therefore, new systems must be promoted using conventional engineering language, and this means performing tests and publishing results using ohms, watts, volts, amps, etc. Acceptance of this premise requires measurement and calculation especially of power and energy to be done properly (see Hathaway in 2nd International Symposium on Non-Conventional Energy Technology, Atlanta, 1983) and that a certain minimum standard of equipment be maintained. Special precautions must be taken when measuring energy efficiency for example, when systems include storage and/or primary batteries or produce commutation or other voltage or current spikes.

There are many steps to be taken in the transformation of ideas and prototypes to commercially available systems. A major issue is the ability to scale these systems to more economical sizes. Also important is the historical perspective: knowing whether a device or technique has already been tried saves time and expense. Above all, inventors must not stand on a pedestal and ignore the rest of physics and engineering.

> "Throughout space there is energy, it is a mere question of time when men will succeed in attaching their machinery to the very wheelwork of Nature."
>
> *Nikola Tesla*

Introduction/Definitions

This paper presents a very brief overview of engineering issues related to the development and commercialization of so-called 'Non-Conventional Energy Technology' (NCET). NCET systems encompass the production, transmission and conversion of all forms of energy derived from sources which are only now beginning to be recogriized but still dimly understood. While the scope of this paper is limited primarily to electrical energy-producing or transforming devices, those that involve mechanical energy, chiefly rotational torque, in their operation, will also be discussed. The paper is aimed principally at those who wish to investigate, engineer and develop NCET systems.

No attempt will be made herein to assess the validity of the various prime movers or energy sources supposedly responsible for the operation of these devices. The claim by researchers that these are hitherto undiscovered primary sources is often met with ridicule and derision by conventional physicists and engineers and yet several such devices have actualiy been produced and their operation verified.[1] Some have been patented in the U.S.[2] Many names are given to these inventions, including energy/power amplifiers, free energy devices, amplifying converters, and many sources are cited as being responsible for the additional energy including zero-point, vacuum fluctuation, sub-quantic, tachyon, gravitational field energy, etc.

One of the first observations that the outsider will make is the lack of clarity evident in pinpointing the actual source of the 'extra' or 'free' energy claimed by virtually all researchers in the field. Many researchers claim to be exploiting an unknown source or sources and are trying to prove this claim to the world, as well as commercialize their inventions.

This paper will simply try to assist in the later process, leaving the theoretical discussion regarding sources to others.[3] lt is because the precise nature of the source is not known that so many NCET researchers have trouble developing their inventions and ideas. lt is worth noting, however, that certain inventors desire above all the acceptance of their theory with the development of the associated invention being a secondary concern (e.g. Newman).[4]

Non-Conventional Energy Technology (NCET) Classifications

The literature covering NCET invariably cites Nikola Tesla as the father of free energy research, principally because of the quote at the beginning of this paper.[5] Apart from an apocryphal story regarding a 1933 Pierce Arrow automobile powered by a shoebox-sized device with an antenna, no concrete evidence of free energy devices produced by Tesla has been uncovered.

NCET can be divided roughly into two main categories: Rotating, or those with at least one rotating component, and stationary, with no rotating parts. This implies a further subdivision into those supplying primarily an electrical load and those capable of supplying both electrical and mechanical loads. Figures 1 and 2 schematically represent a proposed classification of some of the most prominent NCET devices progressing from simple to complex. The power figures associated with each type below should be viewed as 'name plate' or 'rated capability', not power produced in excess of input, except where noted.

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[1] For example:
-Hurst, R., "The Invention of Hans Coler Relating to an Alleged New Source of Power." British Intelligence Objectives Subcomiuittee, BIOS Final Report #1043 item #31. London, Great Britain; undated.
-Zinsser, R.G., "Mechanical Energy from Anisotropic Gravitational Fields (MEGA), A Novel Source of Clean Regenerative Energy." Zinsser Innovation GmbH. Idar-Oberstein, West Germany, 1983.
-Moray, T.H., The Sea of Energy. Cosray Research Institute, Inc.. Salt Lake City, Utah, 1978.
[2] For example:
-Gray, E., "Pulsed Capacitor Discharge Engine." US patent #3,890,548. June 17, 1975.
-Alexander, R.W., "Method and Apparatus for Increasing Electric Power." US Patent #3,913,004. October 14, 1975.
[3] More theoretical discussions can be found in:
-1st International Symposium on Non-Conventional Energy Technology Proceedings. G. D. Hathaway, editor. University of Toronto, Canada. October, 1981.
-2nd International Symposium on Non-Conventional Energy Technology Proceedings. Atlanta, Georgia. September 1983.
-1984 International Tesla Symposium Proceedings. International Tesla Society, Inc.. Colorado Springs, Colorado. August 1984.
[4] See The Institute (page 10). IEEE. January 1986. and Science (page 571). Volume 223. February 10, 1984.
[5] As well as a short section entitled "Departure from Known Methods – Possibiity of A Self-Acting Engine", in Nikola Tesla's article "The Problem of Increasing Human Energy", found in Century Illustrated Monthly Magazine, June 1900.

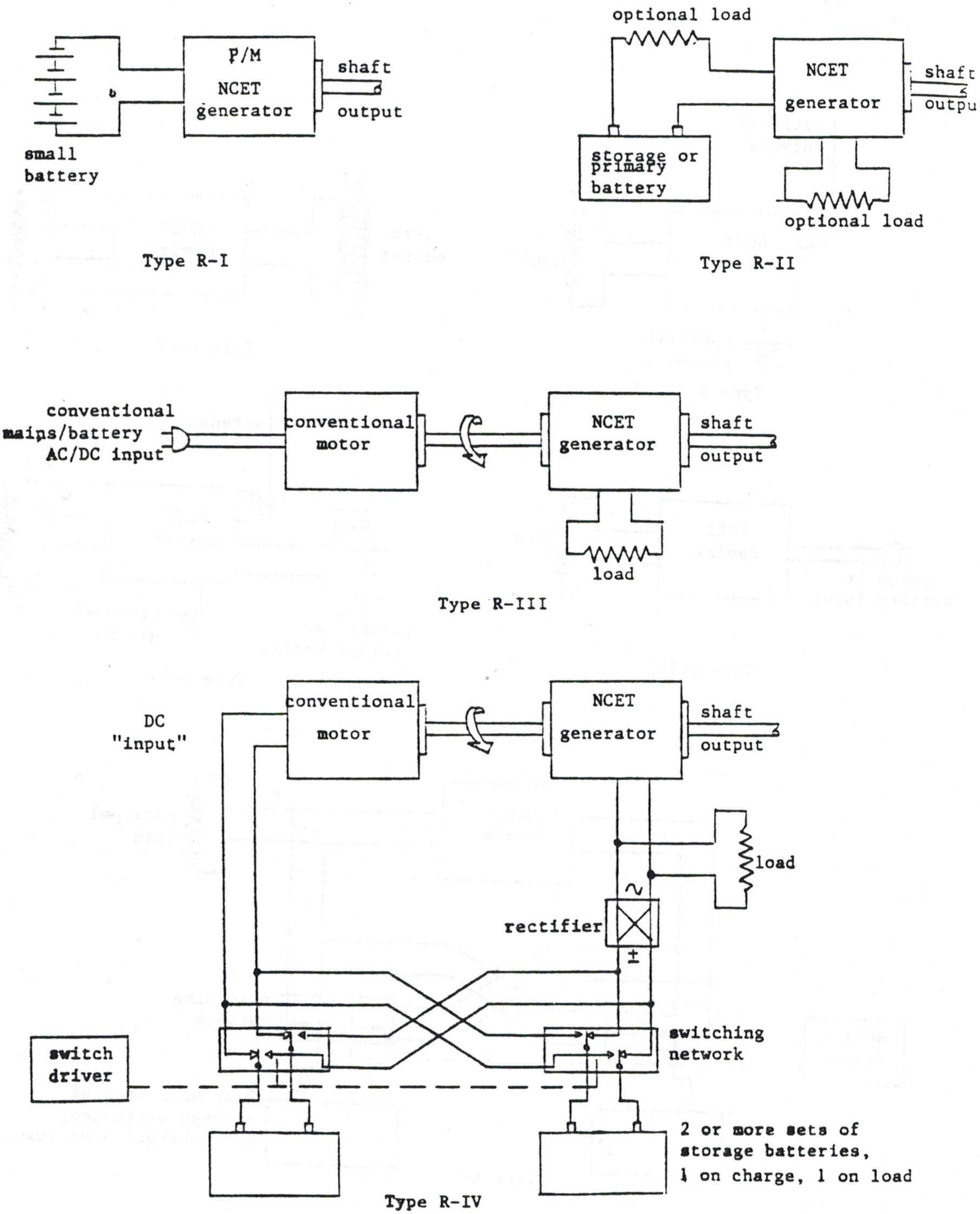

Figure 1. Rotary NCET Devices

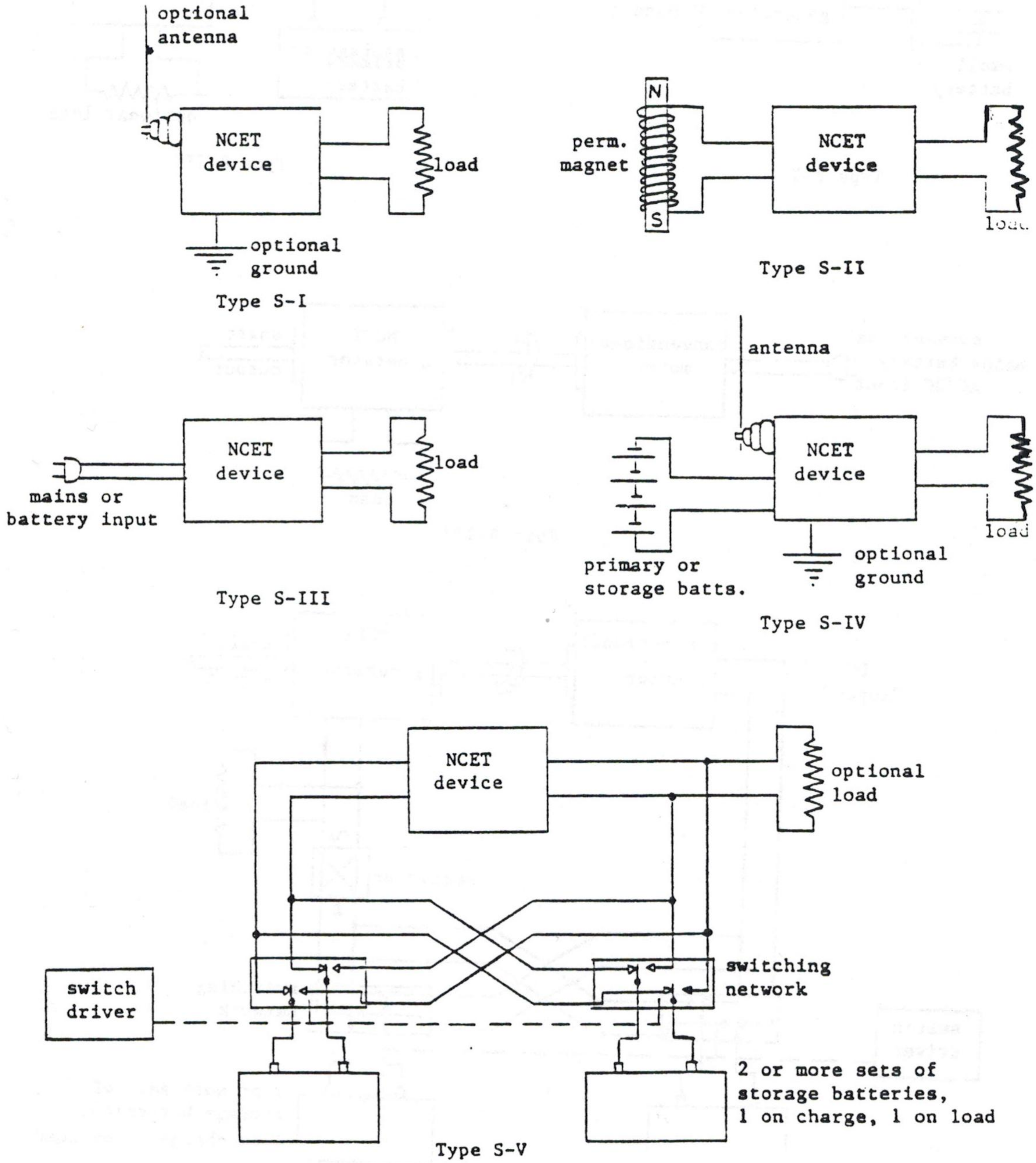

Figure 2. Stationary NCET Devices

The rotating category encompasses 4 types. Type R-I includes attempts to produce permanent magnet generators (or more primarily engines) either continuously self-rotating (not attained yet!) of the Howard Johnson[6] type or given a little kick each revolution of the Kure-Tekko type. The usual object here is to couple this rotating shaft output to a conventional generator producing electric power in the tenths of watt range so far.

Type R-II has recently made headlines in the form of the Newman device. This type encompasses two-terminal devices with a rotating shaft providing optional output torque as well as, in some designs, extra terminals for electrical load. The device is usually operated as a battery recharger which, according to its proponents, rotates the shaft, taking energy from the battery, while it simultaneously recharges the battery (all in a 2-terminal device!). Outputs are in the few tens to few hundreds of watts.

Devices of Type R-IH are essentially motor-generator sets wherein the generator is of special design, allowing the production of free power, usually in excess of either shaft power or input electrical power to the driving motor. Loading is usuaily electrical with optional shaft use. Devices constructed by Bedini and Watson, based apparently on the designs of Raymond Kromrey[7], variable reluctance devices of Mueller and Ecklin, and the ‘N-machines’ of Depalma, Trombly and Marinov, are of this type. The DePalma, Trombly and Marinov generators are special cases of the Faraday Homopolar Generator. The design of Robert Alexander, however, incorporates motor and generator on the same rotor and in the same armature slots. Output powers range from a few tens of watts to several kilowatts.

Type R-IV devices are similar to Type R-III except that the energy required to drive the motor is derived from a battery which, by a sequential automatic switching arrangement, has just been charged by the generator it is driving. Both shaft output, as in the case of the Jameson Energizer and an alternate version of Alexander's above-mentioned device, as well as electric output, is available. Edwin Gray's pulsed capacitive discharge engine is somewhat similar in operation to Type R-IV. Power outputs are in the same range as Type R-III.

There are 5 types in the stationary category. The first includes one of the most celebrated free energy devices – the Moray Radiant Energy generator. This type consists of discrete components, tubes or transistors and resonant circuits usually driven by a multivibrator arrangement. The Moray device used a long-wire antenna and earth ground coupled to the resonant circuits and some claim it derived its initial energy from a small radioactive source. True free energy in the 5-kilowatts range has been documented for this device. The device of Lester Hendershot used neither antenna nor ground, nor tubes nor transistors to achieve useable power output (500 watts AC continuous). Both of these devices apparently produced AC power at a frequency of between 60 and 1000 Hz.

Type S-II uses permanent magnets intimately connected to a parallel set of resonant circuits containing LC elements only. The ‘Magnetstromapparat’ of Hans Coler invented in the 1930's was of this type and allegedly produced up to 10-12 watts continuously of ‘free’ power.

Type S-III includes a type of stationary, flux switching or flux enhancing transformers of unique design. In the Frank Richardson device as well as a second invention of Coler, permanent magnets are used as the flux enhancers. The Hubbard and Volkrodt designs, however, use a specially constructed resonant transformer with tuned input and output operating at high frequencies (up to a few megahertz in the Volkrodt case). Power output is claimed to range from a few hundred watts to a few kilowatts.

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[6] Most of the NCET devices listed in this chapter are described in more detail in Don A. Kelly's Manual of Free Energy Devices and Systems, Electrodyne Corporation, Clearwater, Florida, May 1986.

[7] 1984 International Tesla Symposium, op. cit. as well as Mueller, E., “Experiments with a Kromrey and a Brandt-Tesla Converter”, Tesla Book Co., Miilbrae, CA, 1984.

Type S-IV is a variant of Type S-I and includes a battery to provide internal switching, usually of multivibrator circuits, with the main energy apparently being drawn in through the antenna. The Tesla Pierce Arrow unit mentioned at the beginning of this section was of this type, as is the ‘X-Tech Battery’. Power outputs range from a few tens of watts to what must have been several kilowatts in the Pierce Arrow case.

Type S-V is a variant of Type R-IV and usually contains either multivibrator or switching circuitry with blocking diodes the purpose of which is to maintain or increase the batteries' state of charge while supplying an optional load. The Bedini battery charging circuit is of this type and is claimed to work with nickel-cadmium and lead-acid storage batteries while providing a few tens to a few hundreds of watts output.

lt should be apparent to the astute reader that the great numbers of different configurations, the inclusion of both two and four-terminal devices plus rotating shafts and storage or primary batteries can lead to difficulties in measuring various parameters including power and energy efficiency and thus ascertaining commercial viability.

Commercialization and Criteria For Success

All researchers desire to see their inventions enhance or replace conventional, present-day systems. Some have only theories which need to be ‘reduced to practice’ in the words of patent law. Others have stumbled onto a device which they believe has great potential. Still others have created a theory, and then constructed a prototype device purportedly proving the theory. There is a tremendous, often unbridgeable gulf, however, between theory and prototype and between prototype and commercial product.

Some (e.g. Newman, Bearden) desire mainly to prove to the rest of the scientific and engineering community at large that their particular theory or hypothesis is correct. They are quite content to leave it up to others to engineer physical manifestations embodying their theory. Others are happy if they can demonstrate a small-scale device which appears to contradict established views. lt is axiomatic, however, that laboratory curiosities will remain such unless developed and put to some use.

One of the most useful endeavors that can be undertaken by NCET researchers is knowing the capabiities and operating parameters of competing conventional systems and investigating the history of their development. As happens all too frequently, researchers have not done their homework and would not have discovered that their particular design was tried and discarded many years previously.[8] Indeed, a tremendous amount of research went into rotating generators especially at the turn of the century in such magazines as the Electrical Experimeter and the Journal of the British Institution of Electrical Engineers.

Knowledge of the competition will also reveal important marketing parameters such as use of exotic materials and manufacturing cost, cost per rated kilowatt, power-to-weight ratio, complexity and reliability criteria, overload capability, shock hazard, environmental impact and, of course, operating efficiencies. lt should also go without saying that NCET devices must be beyond the ‘you should have been here yesterday, it was running perfectly’ stage of demonstration. Also useful, especially in the latter stages of development, is knowledge of the certification process, e.g. CSA in Canada and UL, etc. in the United States.

One critical issue which will not be dealt with in this paper is the financing and support of NCET. This is the subject of an entire paper in itself, and the reader is referred elsewhere for such information.[9]

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[8] A good example is the variable-reluctance or ‘Magneto’ generator, Type R-Ill, used as a high-speed, high-frequency, low-efficiency generator on World War II aircraft.

[9] Reynolds, J.. “Financing Primary Energy Technology.” 1st International Symposium on Non-Conventional Energy Technology. op. cit. page 97.

The primary purpose of the remainder of this paper is to identify and clarify some fundamental engineering and measurement issues involved in converting these ideas and devices into useful products capable of standing alongside or replacing conventional units providing the same service.

NCET Efficiency

The ultimate engineering test of an invention's viability is whether it outperforms currently available conventional devices, or will do so in the near future given reasonable time and funding. The only way to determine the extent of this performance is by making comparisons in terms applicable to conventional systems.

Therefore, new systems must also be investigated and promoted using conventional engineering language (i.e. that which measures conventional systems) and this means performing tests and publishing results using ohms, watts, volts, amps, etc. Since the goal of all of the NCET discussed herein is the provision of rotational or electrical energy, energy and its time derivative, power, must be measured and calculated carefully, accurately and consistently. Although it is possible and even desirable to measure such factors as transient, frequency and phase response, these are not required when determining first-order energy or power production or efficiency. These factors enable the researcher to obtain a clearer understanding of the operation of the system but are usually beyond the capabilities of most experimenters. They are important, of course, when optimizing or improving the design and especially when matching device to load.

lt is claimed by many researchers in NCET that their device is ‘over efficient’, ‘super efficient’, or ‘over unity’, meaning that the total output energy (or, more often, power) exceeds input. This implies that there is a definable input and output to begin with. lt follows that the device must have either four electrical terminals (at least) or two terminals plus rotating shaft. One of the usual pitfalls into which researchers fall is their imprecise definition of output and input, especially if their designs incorporate storage batteries and/or are essentially two terminal devices.

lt is a given, however, that those two terminal devices devoid of batteries or input rotating shafts, such as Types S-I and S-II, which produce energy above a certain amount are true free-energy devices provided their energy outputs are measured correctly. If one wishes to measure in detail their input/output energy efficiencies, however, one must have considerable knowledge of the true source of the driving energy, something which as of this writing, is not available yet. Therefore, if a device is to be called over-unity efficient, its input and its output must be well-defined and available for measurement. Major problems are encountered in this respect for Types R-II, R-IV and R-V.

Conventional power electrical engineering, when measuring rotating machines such as generators and motors, use a method of calculating overall operating efficiency which involves measured electrical output and calculated and measured losses within the machine. This is due to the inherent difficulties in measuring, for large electric generators for instance, the driving shaft torque and therefore input power. Because of the generally detailed knowledge of the nature and size of the losses in such machines, this method of efficiency calculation has been found to match very closely the calculation of true efficiency:

Large Rotating Machines -

$$\eta = \frac{\text{OUTPUT}}{\text{OUTPUT + LOSSES}} \qquad (1)$$

True Efficiency -

$$\eta = \frac{\text{OUTPUT}}{\text{INPUT}} \qquad (2)$$

where η = efficiency.

This difference should be kept in mind when comparing rotating NCET devices with their conventional counterparts.

Common Misconceptions

Before discussing the basic engineering measurements necessary for the assessment of performance, it is instructive to examine some common misconceptions held by free energy researchers. Unfortunately, most literature concerning free energy measurements and calculations abounds in misunderstandings of principles and characteristics or misapplication of technique. These can range from simple to complex depending on the system and generally indicate a failure to investigate or apply the proper technique or calculation. This is the ‘high school’ level approach to ‘university’ level problems. lt is most often caused by the researcher's over-enthusiasm at the excitement of having made an apparent breakthrough although on rare occasions it is pre-meditated intent to deceive. The eagerness to publish should never be given greater importance than the integrity of the contents.[10]

Several recent NCET investigators have concentrated on the storage battery-based systems of Types S-V, R-II and R-IV. The main problem here is that such systems must be characterized using *energy* measurements and calculations rather than power only. This is especially true in any system that alternately charges and loads a set of storage batteries such as lead-acid or nickel-cadmium and is claimed to act like a self-powered battery charger. Without adding the essential time component, no direct comparison with conventional systems is valid. This must be done on an energy-to-energy basis.

Coupled with this is the chronic underestimation of current lead-acid batteries’ energy storage capabiities and tendency to self-recharge after heavy loading. The researcher is urged most strongly, therefore, to perform simple load tests on the storage batteries to be used to make sure they understand the batteries’ capabilities in conventional circuits.

lt is also known that enhanced charging of storage as well as to a lesser extent, primary batteries is possible by high-frequency resonant and non-resonant pulsing. This phenomenon is stumbled upon by many researchers but it operates at less than unity efficiency when properly measured. lt is important to note, however, that measurement of the energy content of such pulses, except in the cases of simple, zero DC-offset waveforms, can be complex and difficult without proper equipment. Enhanced charging at high currents is possible, but battery life will be severely foreshortened and it is a dangerous practice due to excess hydrogen devolution and plate buckling causing internal shorts.

Another popular misunderstanding regarding storage batteries is the measurement of their state of charge. For a few NCET devices involving battery charging, e.g. Bedini, this is the main performance criteria that is ‘measured’ to demonstrate over-unity efficiency. Unfortunately, virtually all NCET researchers experimenting with these types of devices equate charge state with terminal voltage only.

lt is apparent that they are really trying to show how much energy is left in the battery after a particular charging or loading operation. If this is correct, then several other factors must be taken into account as well as voltage including specific gravity, pH, age, temperature, current draw curve over a short duration, etc. All of these factors must be compared to the battery manufacturer’s data to determine actual charge state and thus remaining capacity (energy). lt must constantly be kept in mmd also that battery discharge curves are non-linear and exhibit knees and breakpoints so that comparing two batteries’ ‘state of charge’ (measured solely by voltage) whose voltage is the same does not mean they have the same remaining capacity stored within, measured as

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[10] For discussion of a recent example, see Hathaway, G.D. “An Examination of Mueller's ‘Experiments with a Kromrey and a Brandt-Tesla Convertor’,” Energy Unlimited, issue #20, 1985(?) page 42.

(instantaneous watts/unit time) times (total time until charge reaches a certain minimum value). Capacity also varies with discharge rate.

Devices of Type R-II, for example, and certain versions of the Newman machine, are essentially two-terminal devices. lt is claimed that in these systems, power flows both ways simultaneously in two wires only from device to battery and from battery to device, thus keeping the battery charged while powering the device. Unless these two wires can be characterized as a high-frequency, multi-mode transmission line with sophisticated multiplexing capabilities at either end, stating that these systems allow simultaneous power flow in both directions at the frequencies specified must be unequivocally demonstrated as being so before this claim is acceptable.

With regard to rotating NCET devices, it is often observed that the shaft speed of NCET generators occasionally increases when an electrical load (usually a short circuit) is placed across their output terminals. This, it is stated, is totally unheard of in conventional physics.[11] This statement embodies two incorrect assumptions, namely that a decrease in rpm always means a decrease in power transmitted by the shaft, and that placing an arbitrary load, usually a short circuit, across the output terminals constitutes 'loading' the generator.

The first of these assumptions can be simply examined. Mechanical power in a rotating shaft is equal to the torque times the angular velocity:

$$P_{mech} = T\omega \qquad (3)$$

where

P_{mech} is the mechanical shaft power
T is the torque (in Newton-meters)
ω is the angular velocity (radians/sec)

If the torque is constant, then the power will be proportional to the rotational speed. However, varying the torque while keeping the speed constant will vary the power. In a simple shunt connected motor, for instance, as armature current increases, torque rises rapidly while rpm falls slightly, demonstrating the variability in the two parameters T and ω.

The second of these assumptions comes from a 'high-school' approach to electrical generators and motors. If the researchers scanned any electrical machines textbook they would discover that in many instances and depending on the wiring of the machine, decreasing the resistance in a certain part of the circuit (sometimes used as the output/input terminals) will inevitably result in a shaft speed increase. This is shown by applying simple laws of conventional electrical engineering. In the example of the fractional horsepower shunt-wound motor used above, decreasing the total armature resistance increases the speed. Therefore, the internal circuit diagram of the NCET generators or motors must be known and examined if such speed versus load claims are to be made.

A corollary misconception related to the foregoing is the assumption that zero resistance equals 'maximum load'. The term 'maximum load' as used by most NCET researchers means that condition which allows maximum power to flow from the source to the load. In electrical technology, that condition means the electrical impedance of both source and load.

[11] Mueller, op. cit.

The most general case has these impedances broken into the resistive or active (real) part and the inductive or reactive (imaginary) part. When the load comprises a purely resistive element, or nearly pure, the imaginary part is negligible and the impedance of the load can be measured in ohms by a simple ohmmeter. Loads such as resistors, light bulbs and heaters can effectively be treated as purely resistive. Motors, etc. when used as loads exhibit generally high inductive impedance along with the purely resistive and should only be used in power measurements by those who are conversant with the calculations involved. This latter only applies to those handling AC. However caution must always be exercised when measuring the impedance of the load.

In general the same applies to characterizing the output impedance of the source. If it contains inductive or capacitive components and its AC output power is to be measured, it will usually show a significant phase shift between current and voltage waveforms. More about this in the section on measurement to follow.

Returning to the maximum load problem above, it is easily shown that maximum power is transferred to the load when the impedances of the load and source are equal. In the purely resistive case, or the DC case, these impedances can be measured as pure resistances by a simple ohmmeter. All NCET devices have non-zero real output impedances – usually ranging from several tens to several thousand ohms. Applying a short circuit across the output terminals, i.e. a near-zero ohm load, therefore does not represent a 'maximum load' since the impedances are different.

Some NCET researchers claim that devices of Type S-I, S-II, S-III, S-IV and sometimes R-II produce excess of output to input of 2-5 watts and it can be shown that the measurement of output power is sound. These researchers should keep in mmd that with tuned low-frequency circuits, it is possible to 'extract' by induction, up to 5 watts of continuous AC power from nearby 60 Hz mains or powerlines.

Several of the NCET devices listed above have been operated in so-called Faraday cages. This is ostensibly to show that ordinary ambient electromagnetic radiation cannot be extracted by the device and that some other energy form must be contributing, for example 'scalar waves'.[12] Researchers must be exceedingly careful, even with well-grounded cages, when they state that the interior of the cage is thus free of ambient electromagnetic radiation at radio frequencies. Low frequencies up to several kilohertz can easily penetrate the walls of all but the most perfectly made cage. Special screening, especially of magnetic components, must be almost seamless and multi-shelled if penetration and inner surface re-radiation is to be avoided, even at higher radio frequencies, e.g. AM.

Frequently, NCET researchers use a comparison of the apparent brightness of a lightbulb or bulbs powered by a 'free energy' device versus bulbs powered by conventional means, usually househobd AC mains. This comparison assumes that when two bulbs glow with approximately equal apparent brightness, the power they consume is the same. Worse, they consider that half apparent brightness means half power consumed. First, the perception of apparent brightness between two bulbs is extremely difficult with the unaided eye. Secondly, since commonly available bulbs and lamps have non-linear light output versus power consumption curves, half apparent brightness does not mean half power.

Basic Engineering Measurements And Apparatus

For most experimenters, what is required is an 'enlightened researcher's' approach to the measurement of such parameters as voltage, current, impedance, power factor, power and energy. This chapter will deal specifically with those measurements which will allow the calculation of effective power and energy. lt is not meant to be an in-depth treatment as only the fundamentals will be covered.

[12] For a detailed treatise on Scalar Waves, see Bearden, T.E., various publications, from Tesla Book Co., Millbrae, CA.

The first part will discuss electrical power measurements and the following parts mechanical (rotational torque) and thermal power measurements.

Basic Engineering Measurements And Apparatus:
Electrical

If the researcher is fortunate enough to be investigating a device whose input and/or output is pure DC, he or she will have a relatively easy time of accurately measuring power. He or she will not have to worry about such nuisances as power factor, phase, complex impedance, etc. Selection of DC voltmeters and ammeters with appropriate accuracy and sensitivity is straightforward. Modern DC voltmeters have such a high input impedance that they present little burden to the circuit. Burden is the term used to describe the amount of power used up in deflecting the meter itself. Ammeters are quite different however and present generally larger burden. Therefore even in DC circuits it is important to set up the ammeter and voltmeter correctly when measuring power, the product of current and voltage. II the voltmeter is of high input impedance, it should be placed directly across the load with the ammeter measuring the current through both load and voltmeter as shown in Figure 3.

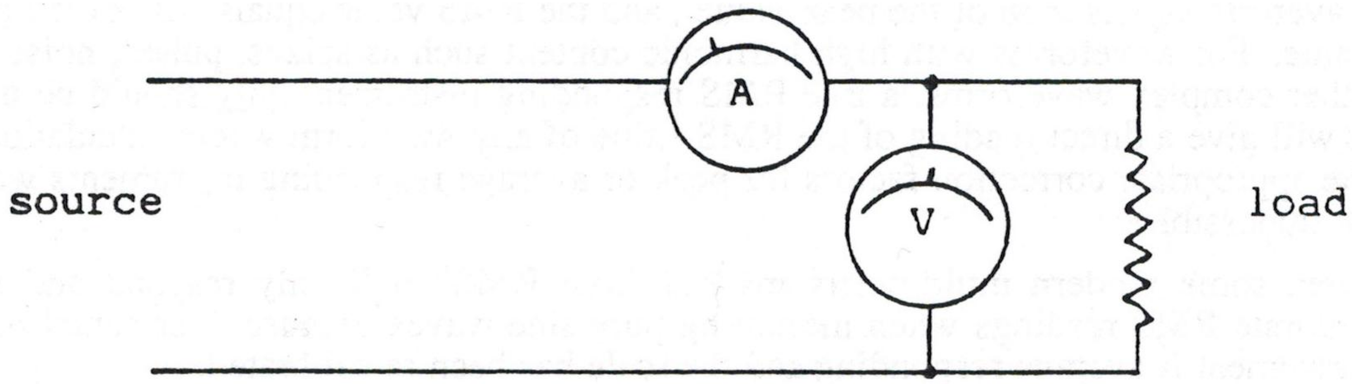

Figure 3. A proper power measurement set-up.

If the meters are of questionable quality, it is necessary to know their impedances and perform a series of simple Ohm's law calculations to correct for burden losses to get true voltage and current figures. This arrangement will also be quite accurate on rectified AC waveforms that have small ripple.

The best meters to use for this purpose are moving-coil, permanent magnet (PM) instruments. These are found in most modern analog multimeters. DC power can also be measured directly using electrodynamometer wattmeters which are described later.

Note the power measured is that consumed by the load, not that produced at the source, since some is used up in the ammeter.

The measurement of AC power can be much more difficult than the DC case especially if non-sinusoidal waveforms are present. There are four main factors to be taken into account when making AC power measurements:

Proper Meter
Proper Load
Phase Angle
Harmonic Content

Basic Engineering Measurements And Apparatus: Proper Meter

Inter-system comparison of AC power and energy demands that the effective values of the parameters (voltage, current and power) be measured. The effective or RMS (root-mean-square) value is that quantity of AC energy that would produce the same heating effect as an equivalent amount of DC energy. lt is thus one measure of the DC equivalent energy. Certain types of meters (and the movements inside some analog multimeters) are calibrated and read directly the RMS value of voltage, current or power. There are various types including electrostatic, thermocouple, iron vane and electrodynamometer instruments and they are generally high-priced. There are two other AC parameter values that can be measured: peak and average. Those interested in insulation breakdown testing or reverse bias values in rectifiers need to be concerned with peak values. Those dealing with electrolysis or magnetic measurements may prefer average values. In this paper, the RMS value is the most important.

The complication arises because a meter whose dial is calibrated in RMS may be a peak or average responding instrument instead and simply have its scale re-calibrated in RMS. For pure sine waves onlv the average value of a current or voltage waveform equals .636 of the peak value, and the RMS value equals .707 of the peak value. For waveforms with high harmonic content such as spikes, pulses, noise and other complex waveforms, a true RMS responding instrument only should be used. lt will give a direct reading of the RMS value of any waveform where calculation of the appropriate carrection factors for peak or average responding instruments would be impossible.

Even some modern multimeters marked ‘true RMS’ will only respond and give accurate RMS readings when measuring pure sine waves because their actual meter movement is average responding and the scale has been re-calibrated.

The best way of measuring power directly (at frequencies up to 400 Hz) is to use an electrodynamometer wattmeter. The schematic is illustrated in Figure 4.

Here, regardless of harmonic content, phase angle etc, a true RMS pawer reading will be available.

At frequencies higher than 400 Hz, rectifier/moving-coil PM meters are required but still have to be calibrated for RMS. Be careful to note the frequency up to which your meter is accurate. For higher frequencies (e.g. RF), thermal calorimetric instruments must be used (see below).

In addition to frequency response, the meters used must not be overloaded or their accuracy will suffer.

Basic Engineering Measurements And Apparatus: Proper Load

For AC power calculations based on separate voltage and current measurements (i.e. not incorporating a wattmeter) the schematic of Figure 3 should be used incorporating RMS or RMS-converted meters. If only one meter (multimeter) is available, it can be switched between the two positions only as long as its voltage-reading input impedance is high (e.g. $\geq 1\ M\Omega$) and its current-reading burden is incorporated in the calculation of power. Some researchers will place their expensive new multimeter across the output terminals of the NCET device and, without touching the connections, turn the range switch from Volts AC to Amps AC and multiply the two readings so obtained. This is totally wrong for there is no real load in the circuit.

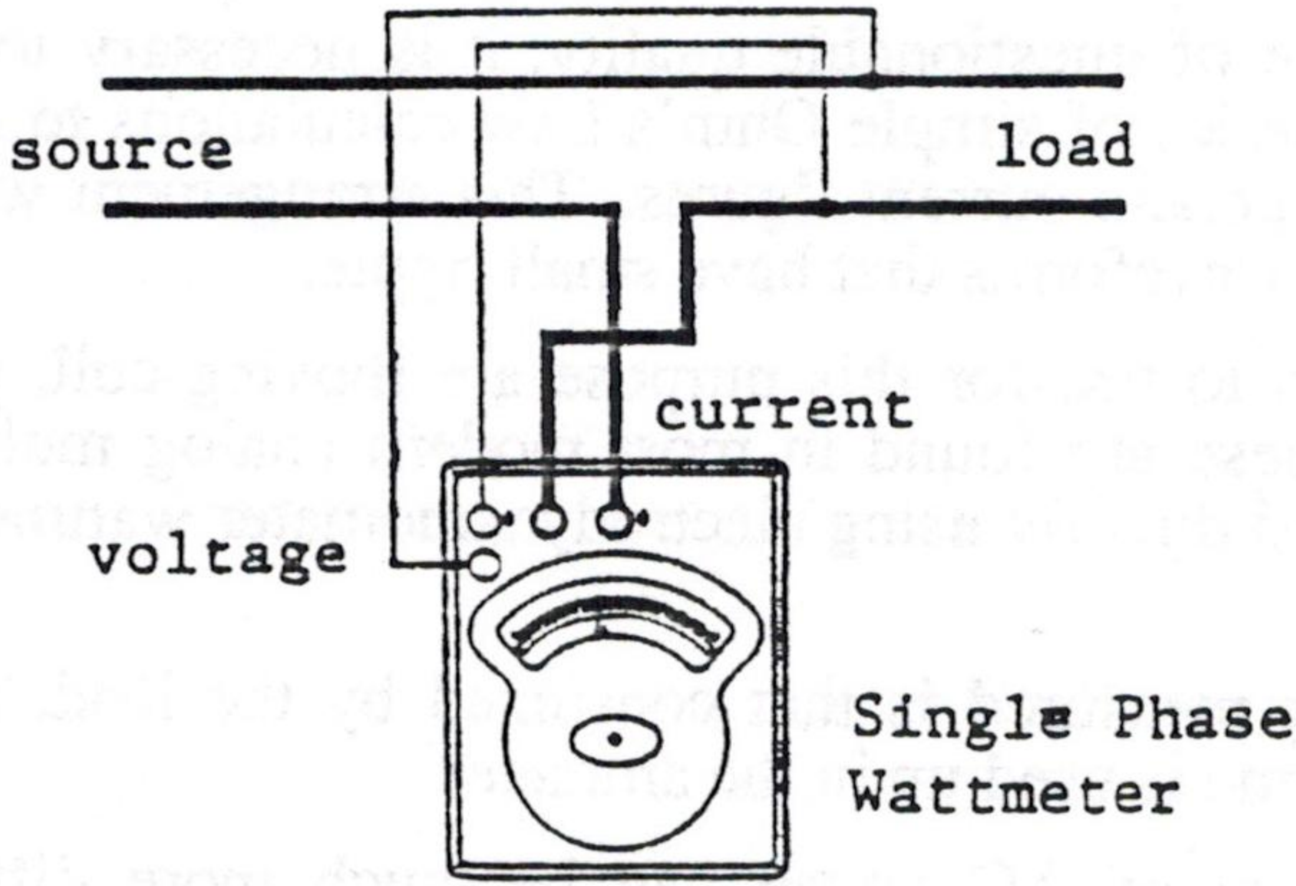

Figure 4. Proper wattmeter setup.

Proper load means the ability to load a device in such a way that it will mimic the kinds of loads it's going to experience in the real world. Although these could be transformers, motors etc. with large reactive impedance components, simple, resistive loads such as resistors, lamps and heaters are acceptable for simple NCET power measurements.

If the load resistance is known with reasonable accuracy (e.g. 1-5%), it is possible to use only an RMS ammeter in series with the purely resistive bad and use the formula:

$$P = 1^2 R \qquad (4)$$

where

1 is the RMS current (amps)
R is the resistance (ohms)
P is the power (watts)

This, again, represents the real or active portion of the power consumed in the load.

Basic Engineering Measurements And Apparatus:
Phase Angle

When measuring power using a wattmeter, a direct power reading is given. When using a separate ammeter and voltmeter an additional factor must be taken into consideration. This is the phase angle, or angular distance between the current and voltage waveforms. The relationship between true power measured using a wattmeter and the current and voltage measurements is:

$$P = EI\cos \Theta \qquad (5)$$

where

P is the power measured using wattmeter (watts)
E is the voltage (volts)
I is the current (amps)
Θ is the phase angle (degrees or radians)

A good way to measure the phase angle is by viewing both current and voltage waveforms on an oscilloscope. The instantaneous power is obtained by multiplying the instantaneous values of the current and the voltage at each instant of time for one whole cycle regardless of the phase angle. The effective value of power is obtained by multiplying the RMS values of current and voltage together times the cosine of the phase distance between the two, measured as angular distance (e.g. degrees or radians).

If one does not have access to an oscilloscope, one can make a guess at the maximum phase angle introduced by the load. If the load is purely resistive (e.g. special 'non-inductive' resistors), the phase angle will be zero, and cos (0°) = 1. If regular light bulbs or coiled heaters are used, the phase angle may vary up to 10 degrees (cos(10°) =.98). Inductive loads such as transformers can introduce angles of up to 90° meaning that the real power consumed will be zero!

Basic Engineering Measurements And Apparatus: Harmonic Content

Most small, home-made NCET generators produce voltage and current waveforms which are not pure sine waves but are composed of a fundamental plus significant (5-25% amplitude) proportions of second and third harmonics. Some appear to be almost square-shaped pulses. To minimize eiectrical losses, large, well-built generators either shape their pole faces or provide some other electromagnetic means for producing pure sine waves. Harmonic content can be simply visualized as the amount of deviation from pure sine waves. lt is very important to know the harmonic content if it is claimed that the NCET device is only a few tens of percent over unity (100%) efficient.

The best way for the NCET researcher to see the harmonics present is by observation of an oscilloscope waveform trace. To actualiy measure exact amplitudes of harmonics with respect to the fundamental, it is necessary to use sophisticated equipment such as wave analyzers or spectrum analyzers. A rough idea of the contribution of second and third harmonics is shown in Figures 5a, 5b, and 5c. Here, 30% (by amplitude) 2nd and 3rd harmonics in-phase are added in Figure 5a and 5b, and in Figure 5c, 3rd harmonic out of phase is added.

For example, the third harmonic may cause a waveform error when using a peak responding meter of from +20 to -33%, or an error of -14% for an average responding instrument, depending on the amplitude and phase of the harmonics.

Basic Engineering Measurements And Apparatus: Mechanical

There are several means available for the measurement of mechanical power in a shaft, depending on its torque-speed relationship. For powers on the order of several tens of kilowatts and up, electrical or hydraulic dynamometers are used. These are generaily quite expensive, and beyond the reach of the average NCET researcher.

Other units employ torsion bars and strain gauges but their calibration can be costiy and time consumirg. These methods are not generally suitable for the NCET researcher unless many such tests over an extended period are to be performed.

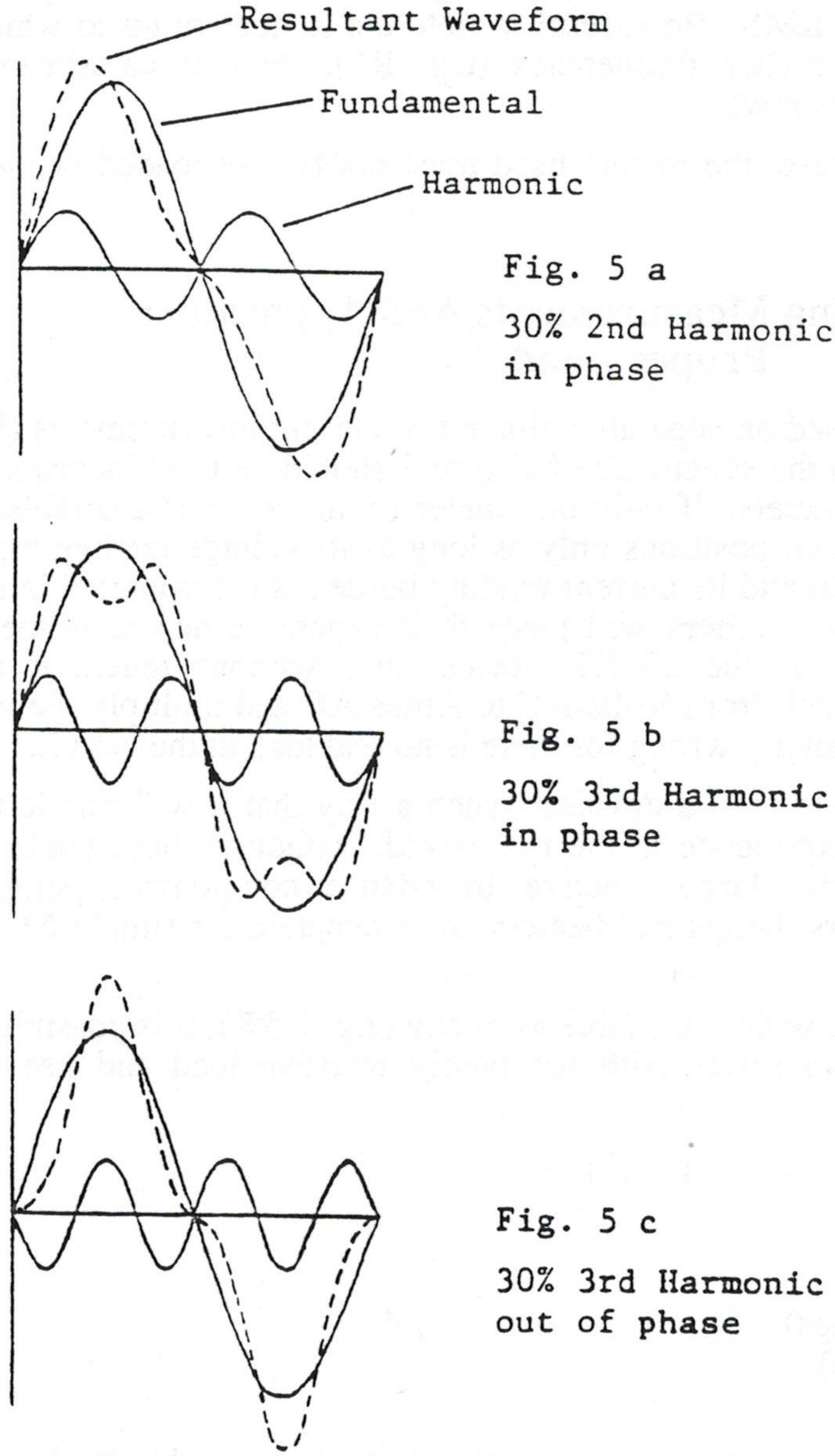

Figure 5. Harmonic relationships.

A simpler method will be described which is well within the capabilities of most NCET researchers – the rope brake shown in Figure 6.

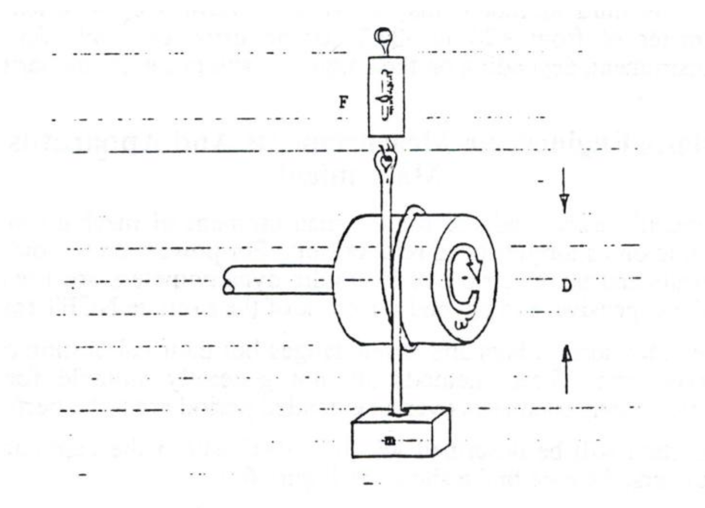

Figure 6. Typical rope brake.

In the rope brake, a loop of rope is wrapped around a flywheel attached to the shaft being measured. One end is attached to a spring balance (e.g. ‘fish scale’) which itself is suspended from a rigid support. The other end of the rope is attached to a known mass. The mass and numbers of turns of rope around the flywheel drum should be adjusted until at the required rpm, the spring balance reads approximately half scale. Obviously, a tachometer is also required for this operation, as well as the correct mass. The brake power is expressed in Formulas 6 and 7.

$$P_{brake} = \tfrac{1}{2}\,\omega D\,(Mg - F) \qquad (6)$$

where

P_{brake} is the brake power (watts)
ω is the angular velocity (radians/sec)
D is the flywheel diameter (meters)
M is the mass (kilograms)
g is the gravitational acceleration 9.8 meters/sec^2
F is the spring balance force (kilograms)

also

$$\omega = \frac{2\pi R}{60} \qquad (7)$$

where

R is the rotational speed (rev/minute)

This method will give results to within the accuracy of the scale balance (= 5-10% with a good scale) provided that the balance is indicating in its linear range (i.e. mid-scale) and that the rope does not get too hot. Therefore it is best to run this brake several times for short durations and average the results. Mass in kg is equal to scale weigth (kg) divided by g.

Basic Engineering Measurements And Apparatus:
Thermal

The thermal, or calorimetric method, is the best overall method of measuring energy and can be easily adapted to measuring electrical energy and power. Essentially, a calorimeter is a heat source placed in a medium (water) whose temperature rise is indicated on a thermometer. Although this method sounds straightforward, several precautions need to be taken.

The heat source is typically an electrical resistor or heater coil operating as the load of an NCET device. Besides the general impedance matching considerations discussed above, the resistor or heating element must be as non-inductive, i.e. purely resistive, as possible. Several straight lengths of nichrome heater wire separated by as great a distance as possible and connected in parallel will do.

Clean tap water can be used to surround the heater element, but this must be contained within a dewar or other equivalent highly thermally insulating bottle. The container itself should be shielded from any ambient thermal agitation, such as air currents, etc., preferably by placing it in an outer box filled with insulating material. lt is also recommended that some means for slowly stirring the water be installed to prevent stratification but for most NCET work this may not be necessary. A thermometer of appropriate sensitivity should be inserted through insulating caps or stoppers.

An electronic thermometer is desirable. The mass of water must also be known so some means of accurately weighing the quantity of water to be used is required. Remember mass (kg) = scale weight (kg)/g.

In operation, the water must be brought to thermal equilibrium within its container. This means leaving the water (and stirrer on, if present) for up to one to two hours until the temperature is constant. Then the load should be connected to the source and the temperature rise and time recorded. If a simple thermometer is used, it is best to allow the temperature to climb as many degrees (minimum of 5-10 degrees C or F) as possible while taking readings. A one or two degree rise from steady-state cannot be used unless the thermometer has an expanded scale. This means that there has to be substantial movement of the mercury or alcohol in the thermometer over as large a portion of the thermometer scale as possible.

The following formula can be used to calculate the total energy produced by the source (NCET device) and converted to heat in the water:

$$E = 4185mc\Delta T \tag{8}$$

where

E is the total heat equivalent energy (joules or watt-seconds)
m is the mass of water (kilograms)
c is the specific heat capacity of water (1 kcal/kg. °C)
T is the temperature difference between the initial and final readings (°C)

If the time taken to reach the final reading is recorded, the average power produced by the device during that time is:

$$P_{avg} = \frac{E}{\Delta t} \tag{9}$$

where

P_{avg} is the average power (watts)
E is defined above (joules or watt-seconds)
Δt is the time interval between initial and final temperature readings.

Conclusions

lt is hoped that this brief summary will provide the basic tools and techniques necessary for the average experimeter to measure and characterize NCET devices. There is obviously much more that can be said regarding specific test and measurement techniques and the serious researcher should consult the local university library or the general references cited at the end of this paper.

The techniques and technology described herein should allow the NCET researcher to organize and present his or her data and results to investors or other interested parties in intelligible language. This will allow others to scrutinize and offer constructive criticism or better, money, for the further advancement of the invention. Once the concept is shown to be valid, a whole different phase of development must be undertaken. This includes addressing such issues as scaling, reliability, safety, consistency of performance, ease of manufacture, etc.

References

-- Collett, C.V. and Hope, A.D., Engineering Measurements. London, Great Britain: Putman Publishing, 1974.
-- Lincoln, E.S., Electrical Measuring Instruments: Measurements and Surveys. New York: Essential Books, 1945.
-- Popov, V., Electrical Measurements. Translated from Russian by Roberts and Ulyanov. Moscow: MIR Publishers, 1982.
-- Siemon, G.R.. Magnetoelectric Devices. New York: Wiley & Sons, 1966.
-- Uiga, E., "The Significance of RMS, Average and Peak Responses." EEE: The Magazine of Circuit Design Engineering. April 1964.

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