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THE MOST GENERAL FORM OF THE VECTOR POTENTIAL IN ELECTRODYNAMICS

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The most general form of the vector potential is deduced in curved spacetime using general relativity. It is shown that the longitudinal and timelike components of the vector potential exist in general and are richly structured. Electromagnetic energy from the vacuum is given by the quaternion valued canonical energy-momentum. It is argued that a dipole intercepts such energy and uses it for the generation of electromotive force. Whittaker's $U(1)$ decomposition of the scalar potential applied to the potential between the poles of a dipole, shows that the dipole continuously receives electromagnetic energy from the complex plane and emits it in real space. The known broken 3-symmetry of the dipole results in a relaxation from 3-flow symmetry to 4-flow symmetry. Considered with its clustering virtual charges of opposite sign, an isolated charge becomes a set of composite dipoles, each having a potential between its poles that, in $U(1)$ electrodynamics, is composed of the Whittaker structure and dynamics. Thus the source charge continuously emits energy in all directions in 3-space while obeying 4-space energy conservation. This resolves the long-vexing problem of the association of the "source" charge and its fields and potentials. In initiating 4-flow symmetry while breaking 3-flow symmetry, the charge, as a set of dipoles, initiates a reordering of a fraction of the surrounding vacuum energy, with the reordering spreading in all directions at the speed of light and involving canonical determinism between time currents and spacial energy currents. This constitutes a giant, spreading negentropy which continues as long as the dipole (or charge) is intact. Some implications of this previously unsuspected giant negentropy are pointed out for the Poynting energy flow theory, and as to how electrical circuits and loads are powered.

Key words: most general form of the vector potential, electromagnetic

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energy from vacuum, giant negentropy of a dipole, source charge as a composite dipole, solution of the source charge problem, Poynting energy flow, powering of electrical power systems.

1. INTRODUCTION

Recently, Sachs [1] deduced the most general form of the field tensor in electrodynamics from a consideration of the irreducible representations of the Einstein group. It was shown [2] that the well developed [3,4,5] theory of $O(3)$ electrodynamics is a sub-structure of the general relativistic theory by Sachs. In this letter, the most general form of the vector potential is deduced from the Sachs theory and shown to contain longitudinal and timelike components. The latter generalizes the Whitaker scalar potential [6] of Maxwell-Heaviside theory, which is developed in flat spacetime in which the electromagnetic field cannot propagate [1]. Therefore, in order to obtain a correctly self-consistent theory of the electromagnetic field, the equivalent of Whittaker's development of the scalar potential [6] has to be deduced in general relativistic form. In Sec. 2, it is shown that the scalar potential is in general part of the quaternion valued vector potential, and can be defined only through a suitable choice of metric for a given experimental setup. In Sec. 3, it is shown that electromagnetic energy is inherent in curved spacetime in the form of a quaternion valued canonical energy-momentum four-vector. This forms part of the four-current in vacuo. In Sec. 4, it is shown that energy from curved spacetime can be intercepted by a dipole and used for the generation of electromotive force. In Sec. 5, the arbitrarily discarded non-diverged Heaviside energy flow surrounding every circuit is restored. In Sec. 6, we propose that, once formed in the primary power source, the source dipole receives energy from the vacuum, transduces it into usable form, and outputs it from the power source terminals. Thus, energy ex-vacuo powers every electrical power system and circuit. In Sec. 7, we briefly point out some implications of energy ex-vacuo.

2. THE MOST GENERAL FORM OF THE VECTOR POTENTIAL

Sachs has demonstrated [1] that the most general form of the vector potential is

$$F_{\rho\gamma} = Q\left[\frac{1}{4}(\kappa_{\rho\gamma}q^{\lambda}q^{*}_{\gamma} + q_{\gamma}q^{\lambda*}\kappa_{\rho\lambda} + q^{\lambda}\kappa^{+}_{\rho\lambda}q^{*}_{\gamma} + q_{\gamma}\kappa^{+}_{\rho\lambda}q^{\lambda+}) + \frac{1}{8}(q_{\rho}q^{*}_{\gamma} - q_{\gamma}q^{*}_{\rho})R\right], \tag{1}$$

where q^λ is a quaternion valued metric with sixteen components in general:

$$q^\lambda = (q^{0\lambda}, q^{1,\lambda}, q^{2,\lambda}, q^{3,\lambda}), \tag{2}$$

$\kappa_{\rho\lambda}$ is quaternion-valued curvature tensor [1], R is the scalar curvature, and Q is a scalar with the units of charge used to pre-multiply both sides of the factorized Einstein field equation in general relativity [1]. This expression can be written as

$$F_{\mu\nu} = \partial_\mu A_\nu^* - \partial_\nu A_\mu^* + \frac{1}{8}\Phi R(q_\mu q_\nu^* - q_\nu q_\mu^*), \tag{3}$$

where the asterisk denotes quaternion conjugation, so that the most general form of the vector potential reads

$$A_\lambda^* = \frac{Q}{4} q_\lambda^* \int (\kappa_{\rho\lambda} q^\lambda + q^\lambda \kappa_{\rho\lambda}^+) dx^\rho \tag{4}$$

and contains four components, including a non-zero timelike component

$$A_0^* = \frac{Q}{4} q_0^* \int (\kappa_{\rho\lambda} q^\lambda + q^\lambda \kappa_{\rho\lambda}^+) dx^\rho, \tag{5}$$

which is richly structured and generalizes Whittaker's [6] expansion of the scalar potential in Maxwell-Heaviside theory. From Eq. (1), however, it can be seen that the electromagnetic field vanishes unless the curvature tensor is non-zero, so, in the flat spacetime of Maxwell-Heaviside theory, the electromagnetic field vanishes. The fundamental reason for this is that special relativity is an asymptotic limit of general relativity, one which is never reached. So a consideration of the irreducible representations of the Einstein group means that curved spacetime is always necessary for the propagation of the electromagnetic field.

Similarly, the most general form of the vector potential vanishes if there is no spacetime curvature, represented by the curvature tensor $\kappa_{\rho\lambda}$, and this includes the timelike part of the quaternion-valued potential, defined by Eq. (5) which is the correct representation of the scalar potential in curved spacetime.

3. CANONICAL ENERGY MOMENTUM IN CURVED SPACETIME

The Einstein equation of general relativity is obtained from the reducible representation [1] if the Einstein group has a metric with ten components, which is increased to the sixteen component q^λ by a consideration of the irreducible representations of the Einstein group. The source term is then the quaternion-valued canonical energy momentum:

$$\kappa T_\rho = \frac{1}{4}(\kappa_{\rho\lambda} q^\lambda + q^\lambda \kappa^+_{\rho\lambda}) + \frac{1}{8} R q_\rho, \tag{6}$$

which exists in curved spacetime. The quaternion valued T_ρ is essentially a gravito-electromagnetic canonical energy-momentum and has sixteen terms in general [1]. Six of these appear in the four-current [1] of curved spacetime, which is a source of the electromagnetic field tensor [1] under all conditions.

It is therefore possible, in principle, to extract electromagnetic energy from the vacuum, energy which can be expressed as

$$En = \int j_\mu A^\mu dV, \tag{7}$$

where j_μ is the most general form of the four-current, and A^μ is the most general form of the vector potential.

In the next section, it is argued that a vacuum electromagnetic 4-energy flow exchange between the time and space domains is initiated by a dipole's broken 3-symmetry. The surface charges of an intercepting circuit diverge a fraction of the outflowing spacial electromagnetic energy current from the dipole into the circuit conductors, producing electromotive force in the circuit. Conservation of energy flow in 3-space is violated, but conservation of energy 4-flow is rigorously maintained, as is permitted in any spacially excited region of spacetime. It is also argued that a much larger, unaccounted spacial energy current is produced from the dipole by its broken 3-symmetry, but misses the circuit, is not diverged, and is discarded by Lorentz's [7] integration of the energy current vector around a closed surface surrounding any volume element of interest. In Sec. 5, we remove this Lorentz integration mechanism to recover the Heaviside non-diverged energy flow component (the dark energy flow). In Sec. 6, we apply the dipole's giant negentropy mechanism to propose the view that all electrical power systems power their external circuits and loads with energy from the vacuum. In Sec. 7, we briefly summarize our findings.

4. GIANT NEGENTROPY FROM THE DIPOLE AS A NEGATIVE RESISTOR

Nature requires 4-space electromagnetic (EM) energy flow conservation, but does not require imposing the *additional condition* of 3-space energy flow conservation. In the case of 4-symmetry only, a symmetry between the flow of energy between the imaginary plane (the time domain) and 3-space is permitted while EM flow symmetry is broken both in the time domain (imaginary plane) alone and in 3-space alone.

This energy flow 4-symmetry without the added 3-symmetry condition includes the direct transduction between energy currents in the time domain and energy currents in 3-space. As shown by Whittaker [6] extending the work of Stoney [8], the scalar potential between the ends of a common dipole initiates and sustains this novel energy 4-flow symmetry.

It follows that any scalar potential and any dipolarity is a true negative resistor, receiving energy in unusable form from the time domain and outputting real energy in 3-space. Any scalar potential, and hence any dipolarity, decomposes in $U(1)$ electrodynamics [9,10] to a harmonic set of longitudinal EM waves in 3-space accompanied by their corresponding phase conjugate replica set, which latter is a harmonic set of longitudinal EM waves in the complex plane. There is a perfect 1:1 correspondence between the phase conjugate waves set in the imaginary plane (in the time domain) and the wave set in the real 3-space. This perfect correspondence between the two sets of waves and their dynamics represents a deterministic re-ordering of a fraction of the 4-vacuum energy in dynamic form, initiated by the formation of the dipole and spreading radially outward at the speed of light.

The expanding negentropic circulation provides a *deterministic vacuum structuring* dynamics associated with the well-known broken 3-space symmetry of the dipole [11] in its energetic exchange with the active vacuum. This reordering of a portion of the vacuum energy expands at the speed of light in all 3-space directions from the dipole, from the moment of formation. The reordering continues spreading radially outward at light speed so long as the dipole — and hence its broken 3-symmetry — remains intact.

If the dipole is suddenly destroyed, the negentropic reorganization of the vacuum energy is suddenly cut off (chopped) at that moment, leaving a thick, expanding spherical shell of reordered vacuum energy, continuing to expand outward at light speed [12].

It follows that any volumetric element in the 4-vacuum is filled with innumerable interactions and dynamics from such negentropic reordering vacuum energy systems — both continuous and chopped — by distant dipoles. These systems comprise dynamic "hidden order" or "hidden variable" processes in the vacuum, including within its statistics. Without further discussion, we propose that this ordering may provide quantum mechanics with a hidden order an an "already chaotic" statistics that integrates coherent microscopic dynamics into macroscopic order, resolving or partially resolving the problem of the missing quantum chaos [13].

There emerge two cases of the Whittaker decomposition of the scalar potential between the dipole ends. First, in observer forward time, the 4-flow of energy is from the time domain into the dipole, with a corresponding flow of 3-space EM energy radially out from the dipole in all directions. This corresponds to the dipole absorbing imaginary EM energy from the time domain of the 4-vacuum (energy absorption from the complex plane), transducing the energy into 3-space energy, and outputting it in all radial directions in 3-space (real EM energy emission).

Second, in reversed time, the flow of energy is convergent from 3-space into the dipole, providing real energy absorption by the dipole charges. These charges transduce the absorbed real 3-space energy into imaginary energy and output it into the time domain (complex plane energy emission).

In the first case, real longitudinal wave EM energy pours out of the dipole without any 3-space energy input. Instead, the energy input is furnished by transduction of the convergent timelike longitudinal EM wave energy input. In the second case, real longitudinal wave EM energy pours into the dipole without any 3-space energy output, with the input energy being transduced in form and output in the complex plane.

In electrical engineering terms, in the first case, the dipole acts as a *true negative resistor*, since it receives EM energy in unusable form (in electrical engineering, *reactive power* form) and outputs it in usable form (*real power* form). In the second case, one has a positive resistor, but a most unusual one since it has no scattering output energy flow in 3-space, even though it has a 3-space energy input. Instead, it scatters its output energy into the complex plane (time domain) as diverging timelike currents, thus transducing spacial energy into timelike energy.

We suggest a useful mental mechanism which models the transduction of real energy into imaginary energy, and *vice versa*, in electrical engineering terms. A charge in an end of the dipole may be said to spin 720° in making one complete rotation. It spins 360° in the imaginary plane, and spins 360° in real 3-space.

For case one (real negative resistor), during its 360° in the imaginary plane, the charge absorbs the converging EM reactive power. During its subsequent 360° rotation in 3-space, it re-radiates the EM energy it has absorbed from the imaginary plane, emitting it as diverging real EM energy [14] in all directions.

In case two, the charge absorbs the input real power during the charge's 360° rotation in 3-space, transduces the absorbed energy by rotating into the complex plane, and re-radiates the energy in the complex plane while rotating therein.

We may also model any isolated observable charge as a specialized set of dipoles. From quantum electrodynamics, consider an isolated observable charge and its clustering virtual charges of opposite sign. Consider one of the virtual charges while it exists, together with a tiny differential element of the observable charge. The two then may be said to compose a momentary dipole, which has a scalar potential between its ends. Call it a "composite" dipole since it is a composite of a virtual charge slightly separated from an element of observable charge.

The scalar potential between each composite dipole's ends may be decomposed in the Whittaker manner [6]. In this sense, an "isolated" observable charge may be considered to be a set of composite dipoles, each of which is continuously forming and un-forming. Applying case one, we see that longitudinal wave energy is continuously input from the time domain to the "charge as a set of composite dipoles," transduced into 3-space energy, and output in all directions in 3-space at light speed. What is *observed* is simply the continuous outflow of electromagnetic energy from the source charge, forming its fields and potentials in 3-space.

This resolves the long-standing classical and quantum electrodynamic problem of the source charge — e.g., as stated by Sen [15] — and its associated fields and potentials, including their energy. The continuous flow of EM energy from the source charge permissibly violates conservation of EM 3-flow energy conservation, but rigorously obeys conservation of 4-flow energy conservation.

The dynamics of the giant negentropy mechanism provide precisely correlated, internal structuring of both the time domain and 3-space. In short, it provides a rich structuring and deterministic internal dynamics of the 4-vacuum, with canonical connection between time-structuring and space-structuring of energy flow as previously shown.

As a set of composite dipoles, the charge thus is also a special kind of composite true negative resistor (actually a great set of such). The sudden appearance of an observable charge (such as an electron lifted from the Dirac sea) initiates an ongoing giant negentropic reordering of a fraction of the vacuum energy, expanding in all directions at light speed and continuing so long as the charge is not destroyed. Charges and dipoles in the original matter of the universe have been pouring out EM energy in 3-space via this mechanism, and producing negentropic reordering of a fraction of the vacuum energy for some 15 billion years [16].

Thus, the charge and the dipole have unexpected properties and symmetries in EM energy flow, and this must be taken into account in any deep analysis of actual EM systems, including electrical power systems. Logically, one cannot continue to advocate the charge as an "independent source" of the energy continuously pouring forth from it and forming its associated fields and potentials, else one advocates creating energy in total violation of the conservation of energy law. As Semiz [17] expresses it:

> *"The very expression 'energy source' is actually a misnomer. As is known since the early days of thermodynamics, and formulated as the first law, energy is conserved in any physical process. Since energy cannot be created or destroyed, nothing can be an energy source, or sink. Devices we call energy sources do not create energy, they convert it from a form not suitable for our needs to a form that is suitable, a form we can do work with."*

In summary, we have proposed a novel negentropy mechanism that resolves both the "source charge" problem and also gives the mechanism of energy conversion by the source charge. After first recovering in Sec. 5 the full magnitude of the energy flow from the dipole that is extracted by this process, we shall use this mechanism in Sec. 6 to propose a fundamental change in the prevailing view of how electrical circuits are powered. The proposed view is also consistent with the known broken symmetry of opposite charges (as on the ends of a dipole) [42] and with quantum field theory's argument that the combination of a scalar photon and a longitudinal photon is observable as the instantaneous scalar potential [43].

5. DARK ENERGY, POYNTING ENERGY, AND THE ENERGY FLOW PROBLEM

In the 1880's, after Maxwell was already deceased, Poynting [18] and Heaviside [19] independently and simultaneously discovered EM energy flow through space. Before that, the concept did not clearly appear in physics. Poynting [18] published prestigiously, while at first Heaviside published more obscurely [19], then more prestigiously [20,21[.

With respect to circuits, from the beginning Poynting assumed only that small amount of EM energy flow that enters the circuit. In Poynting's [22] own words:

> *"This paper describes a hypothesis as to the connexion between current in conductors and the transfer of electric and magnetic inductions in the surrounding field. The hypothesis is suggested by the mode of transfer of energy in the electromagnetic field, resulting from Maxwell's equations investigated in a former paper ("Phil. Trans.," vol. 175, pp. 3430361, 1884). It was there shown that, according to Maxwell's electromagnetic theory, the energy which is dissipated in the circuit is transferred through the medium, always moving perpendicularly to the plane containing the lines of electric and magnetic intensity, and that it comes into the conductor from the surrounding insulator, not flowing along the wire."*

As can be seen, Poynting considered only the *intercepted* energy flow actually entering the wire, and subsequently dissipated in the circuit [23]. He erred by 90° in the direction of the energy flow around the wire, and was later corrected by Heaviside.

Heaviside did understand that the component of energy flow not diverged into the circuit was enormous [21], mentioning that the component entering the circuit was sufficiently small that the remaining component was still nearly parallel to the conductors. Poynting never considered the huge EM energy flow component around the circuit that is *not* diverged, *misses* the circuit entirely, *does not* contribute to the energy dissipated by the circuit, and is *wasted* [24]. In addition, to the intercepted Poynting energy flow component, there remains that vast "dark energy" Heaviside flow component associated with every circuit and dipolar interaction and unaccounted [25].

In the 1880s, there was no explanation as to where such a startlingly large EM energy flow — pouring from the terminals of every dipole, generator, or battery — could possibly be coming from. Consequently, Heaviside was very cautious in referring to it, speaking obliquely in terms of the field angles and components. In Heaviside's [26] words:

> *"It [the energy transfer flow] takes place, in the vicinity of the wire, very nearly parallel to it, with a slight slope towards the wire .... Prof. Poynting, on the other hand, holds a different view, representing the transfer as nearly perpendicular to a wire, i.e., with a slight departure from the vertical. This difference of a quadrant can, I think, only arise from what seems to be a misconception on his part as to the nature of the electric field in the vicinity of a wire supporting electric current. The lines of electric force are nearly perpendicular to the wire. The departure from perpendicularity is usually so small that I have sometimes spoken of them as being perpendicular to it, as they practically are, before I recognized the great physical important of the slight departure. It causes the convergence of energy into the wire."*

As can be seen, Heaviside was aware that the remaining component was so large that the energy flow vector remaining — after the divergence of the Poynting component into the circuit — was still almost parallel to the conductors. Though his words were understandably cautious, there is no doubt that he recognized the enormity of the non-diverged EM energy flow component.

We call that huge dark energy flow component the "Heaviside component" in his honor, since Heaviside discovered it. By the word "dark," we mean "unaccounted" or "arbitrarily discarded," which hides it from scientific view.

Lorentz faced the terrible dark energy flow problem so quietly raised by Heaviside. Lorentz understood the presence of the tiny Poynting component, and also of the very large Heaviside component, but could find no explanation for the startling magnitude of the EM energy pouring out of the terminals of the power source (pouring from the source dipole).

Unable to *solve* the dark energy flow problem by any rational means, Lorentz found a clever way to *avoid* it. He reasoned that the non-diverged Heaviside component was "physically insignificant" (his term) because it did not enter the circuit and power any part of it, and could thus be discarded.

To eliminate the bothersome dark energy flow component, Lorentz [7] simply integrated the energy flow vector (the vector representing the sum of both the Heaviside *non-diverged* component and the Poynting *diverged* component) around an assumed closed surface enclosing any volume of interest. *A priori*, this procedure discards the dark *Heaviside* non-diverged energy flow component and retains the intercepted *Poynting* diverged component that enters the circuit. A century later, electrodynamics still avoids the dark energy flow problem by continuing to use the Lorentz integration procedure [27] to dispose of all but the Poynting component that enters the circuit and is then dissipated by the circuit. As a result, the "Poynting energy flow" has come to be loosely and erroneously regarded as "the" EM energy flow associated with the circuit, though electrodynamicists find it necessary to give stringent warnings about it. Panofsky and Phillips [28], e.g., state it this way:

> *" ... only the entire surface integral of N [their notation for the Poynting vector] contributes to the energy balance. Paradoxical results may be obtained if one tries to identify the Poynting vector with the energy flow per unit area at any point."*

Most electrodynamicists note the freedom to add a vector — few call it an *energy flow* vector, though that is the type of vector being discussed, and one must add apples to apples — which has zero divergence. Jones [29] states:

> *"It is possible to introduce the Poynting vector $\boldsymbol{S}$, defined by $\boldsymbol{S} = \boldsymbol{E} \times \boldsymbol{H}$, and regard it as the intensity of energy flow at a point. This procedure is open to criticism since we could add to $\boldsymbol{S}$ any vector whose divergence is zero without affecting [the basic integration procedure's result]."*

Jackson [30] says it plainly, and also uses Lorentz's "no physical significance" argument for disposing of any energy flow vector with a zero divergence. Quoting Jackson [30]:

> *" ... the Poynting vector is arbitrary to the extent that the curl of any vector field can be added to it. Such an added term can, however, have no physical consequences."*

Any energy flow vector which is the curl of a vector field will have zero divergence, by elementary vector algebra. To be pertinent, the vector added must be an *energy flow* vector since energy flow is what $\mathbf{S} = \mathbf{E} \times \mathbf{H}$ is about [31,32]. Since the curl of any vector has no divergence *a priori*, then any energy flow vector that is a curl of a vector field will be part of the Heaviside dark energy flow component, rather than part of the Poynting energy flow component. It will also be discarded by Lorentz's closed surface integration.

It is a *non-sequitur* to assume that such a divergence-free energy flow vector (dark energy flow) *cannot* have physical consequences. That assumption is valid only if nothing further is done to *intercept* some of the dark energy flow and use the additional collected energy. It also arbitrarily ignores the gravitational consequences of the energy. Energy curves spacetime, whether one accounts for it or not, and such an enormous [33] energy flow may have significant large-scale gravitational effects [25]. Also, if one inserts *intercepting charges* into that non-diverged energy flow component, the charges will immediately diverge some of the formerly non-diverged energy flow around them and hence "collect additional energy" [38]. That is a useful physical consequence, since the collected energy is diverged and therefore converted to the Poynting energy component. There are other consequences of the dark energy also, such as the mechanism we used in deriving the giant negentropy of the dipole. There, the input of a non-Poynting energy flow component from the time-domain certainly has universal and physical significance. Also, we have previously pointed out [34] that retro-reflecting the dark energy flow component back across the *circuit, after that flow has already missed the circuit and passed it by,* will result in additional interception and collection (and an additional Poynting energy flow component) by the circuit's surface charges.

A few electrodynamicists hint at the non-measured dark energy flow. Schwarz [35] expresses it this way:

> *"There will be many opportunities in which the interpretation* $\boldsymbol{E} \times \boldsymbol{H}$ *as a rate of flow of energy per unit area will be profitable. In most cases of practical interest, such an interpretation is valid, although it must always be kept in mind that only the integral of* $\boldsymbol{S}$ *over a closed surface can be physically measured ... Just how it is that the connections to the energy source, say a battery, are at the ends of the wire, yet energy flows in through the sides, should be pondered by the reader."*

Others state the problem, then fall back upon the Lorentz closed surface integration method again. As an example, Jones [36] discusses potential changes to the Poynting vector and presents many conditions the changed vector must fulfill. Then he falls back on the Lorentz closed surface method again, and then (i) includes both the diverged and non-diverged component, and (ii) invokes a procedure that arbitrarily discards the non-diverged component. In thus both recognizing and disposing of the problem, Jones says:

> *"It does not seem likely that an expression satisfying all these conditions will be simple ... ... fortunately, we are rarely concerned with the energy flow at a point. In most applications, we need the rate at which energy is crossing a closed surface."*

Finally, we note that the debate on what the Poynting vector *is*, is still an issue. As an example, a polite debate on the subject has been ongoing for more than 30 years in *Am. J. Phys.* alone [37].

6. HOW ELECTRICAL CIRCUITS ARE POWERED

Oddly, to power their external circuits and loads, batteries and generators do not use their available internal energy — the shaft energy we input to the generator, or the chemical energy available in the battery. Instead, neglecting its internal losses, each uses its available energy to perform work upon its own internal charges and force them apart, thereby forming a *source dipole* connected to the terminals. Batteries and generators expend their internal available energy to make the source dipole, nothing else. None of the internal energy is used to power the external circuit.

Once the source dipole is formed, its giant negentropy results in the dipole continuously receiving unusable reactive power from the time domain of the 4-vacuum, transducing the received energy into 3-space energy, and emitting 3-energy flow that pours from the terminals and through space around the circuit. This energy flow fills all space surrounding the conductors and the rest of the circuit [38].

A tiny "boundary layer" of the energy flow along the conductors and components strikes the surface charges and is diverged into the circuit. All the rest of the giant energy flow surrounding the circuit is wasted (in the single-pass circuit).

The collected Poynting energy in the circuit excites it and asymmetrically regauges it. *Gauge freedom* assures us that, in theory, this increase of the potential energy in the system is essentially free and requires no input by the operator. In real systems, a little switching losses or other losses may occur. Gauge freedom then assures that this excess potential energy can subsequently be discharged in loads to power them, without additional energy input by the operator. Again, in real systems, some switching losses and other losses do occur.

However, in the closed current loop circuit [39], for each potentialized electron dissipating its excess energy in the loads and losses, a corresponding de-potentialized electron must be forcibly returned from the ground return line back through the source dipole, against the emf. Hence, this circuit demonstrates equal back emf and forward emf. Work is performed by the potentialized circuit's forward emf upon the external loads and losses by the circuit, and equal work is performed to force the ground return electrons through the back emf, and therefore through the source dipole, scattering its charges and destroying the dipole. In short, more work is performed to destroy the source dipole than is dissipated by the circuit as useful work in the load. Additional energy must then be input into the system to restore the source dipole. For a 100% efficient input process, we must input at least as much energy to *reform* the dipole charges as was expended by the circuit in *scattering them and destroying* the dipole. Consequently, we must continually input more energy to reform the source dipole than the circuit delivers to power the loads. The system's coefficient of performance (joules of useful work out, per joule of operator energy input) is thus COP < 1.0 [40].

In short, the conventional power system engages in a giant wrestling match inside its generator or other power source, and *loses*. Again, we have previously pointed out [34] more than a dozen ways to approach overcoming this system design difficulty.

7. CONCLUSION

We conclude that every electrical load and every electrical circuit are, and always have been, powered by EM energy extracted from the vacuum via the dipole's giant negentropic process. The energy input to the system by the operator is dissipated only to continually reform the source dipole that the system continually destroys. This strongly suggests that electrical power systems should be fundamentally redesigned away from the present closed unitary current loop design. It also places a different perspective on the prevailing scientific notion that practical electrical energy extracted from the vacuum will be a most difficult technology to develop, and perhaps will only arrive during the next century. Instead, there has never been any other kind of electrical power technology. We have just not properly understood the source of the energy actually furnished to the power line and to the external circuits of the generators and batteries.

We also argue that enormous and usable Heaviside dark energy flow already surrounds every circuit and power line, and it is available for additional energy interception, collection, and use. Proven experiments, such as the Bohren experiment [31] and negative resonance absorption (excess emission), [41] exist to show that the dark energy flow component is present and that electromagnetic energy can be extracted from it and physically utilized.

Finally, we have advanced our finding that energy from the time domain has always powered all our electrical power systems and circuits, and still does. Formation of dipoles and their continuing giant negentropy is straightforward and can be done anywhere in the universe. The 4-vacuum, including its time-domain, is ubiquitous and provides an inexhaustible source of electrical energy taken by such means. We urge the scientific community to focus significant attention and effort on this new view of "unlimited EM energy from the time domain," to provide a rapid solution to the ever increasing electrical energy crisis presently augmenting the economic stress on all nations.

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7. In the latter 1880s, Lorentz apparently introduced this method of discarding the huge non-intercepted, non-diverged component of the electromagnetic energy flow which he stated has "no physical significance." His use of the method is shown in H. A. Lorentz, *Vorlesungen über theoretische Physik an der Universität Leiden*, Vol. V, *Die Maxwellsche Theorie (1900-1902)* (Akademische Verlagsgesellschaft, Leipzig, 1931), *Die Energie im elektromagnetischen Feld*, pp. 179-186. Figure 25 on p. 185 shows Lorentz's concept of integrating the Poynting vector around a closed cylindrical surface surrounding a volumetric element.
8. G. Johnstone Stoney, *Phil. Mag.* **42**, 332 (1896); **43**, 139, 273, 368 (1897).
9. In $U(1)$, the scalar potential identically is the Whittaker decomposition wave sets. In the combined $O(3)$ and Sachs theory, the structure of the potential is much richer. For useful energy from the vacuum for electrical power systems, $U(1)$ theory suffices for our purposes in this paper.
10. On the other hand, in $O(3)$ electrodynamics, the scalar potential can decompose into a far richer internal structure and dynamics than given by the $U(1)$ Whittaker decomposition. In this case, such a scalar potential may contain specific deterministic sets of space-time curvatures, constituting a special kind of "engine" which can conceivably act upon any and all internal levels of a mass located in the structured potential.
11. T. D. Lee, *Particle Physics and Introduction to Field Theory* (Harwood, New York, 1981), p. 184.
12. We hypothesize that the giant negentropy dynamics are ongoing into the virtual state charges and dipoles as well, so that the spreading "chopped" reordering is an energetic, internally structured system in the vacuum energy itself.

13. For a discussion of the problem see P. V. Elyutin, *Sov. Phys. Usp.* **31**, 597 (1988).
14. Strictly speaking, work is the changing of the form of some energy, and power is the rate of performing work (rate of changing that energy). Simple energy flow rate in joules per second has no *power* per se, since the energy is not being changed in form and no work is being done. However, electrical engineers use the term "electrical power" and "drawing power from the source" in the sense of what could be done in the form of work, were the energy to be dissipated in performing the work. We have used the term "power" in that electrical engineering manner to orient toward electrical power systems in terms familiar to electrical power system engineers.
15. D. K. Sen, *Fields and/or Particles* (Academic, London, 1968), p. viii.
16. Potential implications for the prevailing view that all systems tend to increasing entropy are apparent, but are not covered in this paper.
17. Ibrahim Semiz, *Am. J. Phys.* **63**, 151 (1995).
18. J. H. Poynting, *Phil. Trans. Roy. Soc. Lond.* **175A**, 343 (1884).
19. Oliver Heaviside, *Electromagnetic Induction and Its Propagation*, a series of 47 sections, published section by section in numerous issues of *The Electrician* during 1885, 1886, and 1887.
20. Oliver Heaviside, *Electromagnetic Theory*, 3 Vols. (Been, London, 1893-1912; 2nd reprint, 1925).
21. Oliver Heaviside, *Phil. Trans. Roy. Soc. Lond.*, **183A**, 423 (1893). Heaviside discusses the Faraday-Maxwell ether medium, outlines his vector algebra for analysis of vectors without quaternions, discusses magnetism, gives the electrodynamic equations in a moving medium, and gives the electrodynamic flux of energy in a stationary medium. On P. 443, he credits Poynting with being the first to discover the formula for energy flow, with Heaviside himself independently discovering and interpreting this flow a little later in an extended form.
22. J. H. Poynting, *Proc. Roy. Soc. Lond.* **38**, 168 (1984-85).
23. We usually measure energy dissipation in and from a circuit. Obviously, the energy dissipating from the circuit must have entered it. Consequently, our instrumental "circuit measurements" will agree with the Poynting calculations. Nonetheless, the measurements do not determine the energy flow associated with a circuit per se, but only with a tiny component of that flow.
24. Neither Heaviside, Poynting, nor Lorentz considered the time-like inflow of "reactive power" to each element of the moving electromagnetic wave in space, since special and general relativity were not yet born, and Whittaker's decomposition of the scalar potential had not been performed.

25. We have previously nominated this Heaviside dark energy flow, associated with and surrounding every field/charge interaction but presently unaccounted, as a candidate for the case of the excess gravity known to be holding together the spiral arms of distant galaxies. See T. E. Bearden, *J. New Energy*, **4**, 4 (2000).
26. Oliver Heaviside, *Electrical Papers*, Vol. 2, 1887, p. 94.
27. E.g., see W. K. H. Panofsky and M. Phillips, *Classical Electricity and Magnetism* (Addison-Wesley, Reading, MA, 1962), 2nd edn., p. 181. W. Gough, J. P. G. Richards, *Eur. J. Phys.* **7**, 195 (1986).
28. Panofsky and Phillips, *ibid.*, p. 180.
29. D. S. Jones, *The Theory of Electromagnetism* (Pergamon, Oxford, 1964), p. 52.
30. J. D. Jackson, *Classical Electrodynamics*, 2nd edn. (Wiley, New York, 1975), p. 237.
31. However, in conventional (older) classical electrodynamics **E** and **H** are not actually "the fields" per se, but are defined and utilized as the local reaction cross section of the field with a unit point static charge. Or, as Feynman put it, in mass free space, the entities represent only the *potentials* for the fields to be produced, *if* a unit point static charge should be made available to interact with them. At best, in space, the fields **E** and **H** in common electrical power system usage reflect the local intensity of the field insofar as its interaction with a *static* charge will be involved. They represent the intensity of the local field interaction *should* it occur with a *static* charge, not the entities themselves. Resonating the reacting charge, e.g., will result in a larger reaction cross-section for the charge, an increase in the apparent "magnitude of the incident field," and consequently an increase in the magnitude of the energy that is absorbed. See Craig F. Bohren, *Am. J. Phys.* **51**, 323 (1983); H. Paul and R. Fischer, ibid., p. 327. The prevailing "definition" of the field as only what is diverted from it, is also a part of the unresolved difficulties with the modern view of EM energy flow.
32. Richard P. Feynman, Robert B. Leighton and Matthew Sands, *The Feynman Lectures on Physics*, Vol. 1 (Addison-Wesley, New York, 1963), pp. 2-4.
33. T. E. Bearden, *J. New Energy* **1**, 60 (1996); *Proceedings, 4th International Energy Conference*, Denver, CO, May 23-27, 1997, p. 16.
34. M. W. Evans, P. K. Anastasovski, T. E. Bearden, *et al.*, *Physica Scripta* **61**, 513 (2000).
35. W. M. Schwarz, *Intermediate Electromagnetic Theory* (Wiley, New York, 1964), pp. 280-281.
36. Jones, *ibid.*, p. 53.
37. For typical points of view, see J. Slepian, *Am. J. Phys.* **19**, 87 (1951). Mario Iona, *ibid.* **31**, 398 (1963). Udo Backhaus and

Klaus Schafer, *ibid.* **54**, 279 (1986). C. J. Carpenter, *IEE Proc. A (UK)* **136A**, 55 (1989). J. A. Ferreira, *IEEE Trans. Edu.* **31**, 257 (1988). Mark A. Heald, *Am J. Phys.* **56**, 540 (1988). The debate has also appeared in many other leading journals, e.g., T. H. Boyer, *Phys. Rev. D* **25**, 3246 (1982). Interestingly, M. Abraham and R. Becker, *The Classical Theory of Electricity and Magnetism* (Blackie, London, 1932), p. 146 and p. 194, give two examples of the controversy over the Poynting vector. Finally, see D. F. Nelson, *Phys. Rev. Lett.* **76**, 47131 (1996), for advanced work requiring a greater generalization of the Poynting vector.

38. A good illustration is shown by John D. Kraus, *Electromagnetics*, 4th edn. (McGraw-Hill, New York, 1992) in Fig. 12-60, *a* and *b*, p. 578.
39. Here, we assume a unitary current loop; i.e., one where the current carriers in all segments of the closed current loop have the same m/q ratio. That is not true, e.g., in a battery-powered system, where the ion current is confined internally between the plates (between the dipole ends) and has a much greater m/q ratio than does the electron current segment of the loop between the outside of the plates through the external circuit. In that case, the two currents have appreciably different response times, and they can be de-phased and decoupled. Bedini has a patent-pending process for such open dissipative battery-powered systems far from thermodynamic equilibrium. For an explanation of the Bedini system, see T. E. Bearden, *Bedini's Method For Forming Negative Resistors in Batteries*, Proc. IC-2000, St. Petersburg, Russia, 2000 (in press; also on *http://www.cheniere.org*).
40. Note that the excitation energy of the circuit is dissipated in a Lorentz symmetrical regauging fashion in the closed unitary current loop. We have previously dealt with the consequences of removing this arbitrarily self-enforced Lorentz excitation regauging; see [34] above.
41. V. S. Letokhov, *Zh. Eksp. Teor. Fiz.* **53**, 1442 (1967); *Contemp. Phys.* **36**, 235 (1995).
42. T. D. Lee, *Phys. Rev.* **104**, 254-259 (1956). T. D. Lee, Reinhard Oehme, and C. N. Yang, *Phys. Rev.* **106**, 340-346 (1957). C. S. Wu *et al.*, *Phys. Rev.* **105**, 1413 (1957). So revolutionary a change was the proof of broken symmetry in early 1957 that Lee and Yang were awarded the Nobel Prize in December of the same year.
43. F. Mandl and G. Shaw, *Quantum Field Theory*, revised edn. (Wiley, New York, 1993), Chap. 5.