The Claim that Neumann's Induction Law Is Consistent with Ampère's Law Rejected

Jan Olof Jonson

***Abstract*—There have been made several efforts to link Ampère´s law to different parts of electromagnetic field theory In this paper Neumann's effort to make his induction law to appear to be consistent with Ampère's law will be studied thoroughly., Since there exists a concept, named "Ampere-Neumann electrodynamics", it has been regarded as necessary to analyze how Neumann derives the connection between induction and Ampère's force law. One conspicuous thing is that he by the electromotive force of the secondary loop is meaning a physical, mechanical force, contrary to what has usually has been understood as an induced voltage. This makes it possible for him to claim his ideas to be consistent with Ampère's law. On the contrary, recent papers have convincingly shown that the Continuity Equation of Electricity is able to explain, how a current is being induced in a secondary circuit, due to an alternate current in the primary circuit. Earlier discoveries that Coulomb's law is able to account for electromagnetic forces, without involving magnetic fields, provides the conceptual background, which makes the use of magnetic fields unnecessary also in connection with induction.**

***Index Terms*—Neumann's induction law, ampère's law, faraday's law of induction, grassmann's force law, coulomb's law.**

I. Introduction

Graneau argues that Ampére's law has been highly appreciated by Maxwell, adding that it had been widely used for 80 years [1], more precisely the first 80 years, which have elapsed since Oerstedt's discovery of electromagnetism in 1820. Graneau is citing Maxwell, the citation repeated here for the reader's convenience: "It is perfect in form, and unassailable in accuracy, and it is summed up in a formula from which all the phenomena may be deduced, and which must always remain the cardinal formula of electrodynamics", [2]. It is due to these great words of appreciation by the master, Maxwell, natural that there have been made several efforts by successors to link Ampère´s law to different parts of today´s widely used concepts; There are many examples, among those Grassmann's effort to make his law (predecessor to the Lorentz force) appear to be consistent with Ampère's law [3]. Regrettably, Grassmann performs a very serious, but simultaneously very simple mathematical error in deriving the equation that is aimed at corroborating his claim [4]. Further, we have Neumann's effort to make his version of the induction law to appear to be consistent with Ampère's law [5]. This will be treated more extensively below. Again, Maxwell's effort to make his own laws to appear to be consistent with Ampère's law by praising Ampère's law [2], however, in no case is giving the relevant reference supporting their claim. Instead, they all rely on the reputation of a high authority (i.e. Ampère), rather than presenting convincing proofs corroborating their own standpoints. However, finally, Jonson has made a successful effort to derive electromagnetic induction, by applying the Continuity Equation of Electricity [6], [7]. The basic reason for daring to use Coulomb's law straightforwardly on moving charges is the discovery that the different propagation delay of the immobile lattice ions and the mobile electrons in a metallic conductor, gives rise to a net Coulomb field that has been misunderstood as a separate 'Lorentz force' [8].

In traditional interpretations the competence of Coulomb's law has been restricted to apply to strictly electrostatic cases, and it has been assumed that all kinds of dynamics with respect to electric charges require the usage of the Lorentz force. Furthermore, in the just mentioned paper [8] it is also being verified by reference to experiments that the Lorentz force fails to correctly predict the force between rectilinear currents, whereas Coulomb's law is successful in the new interpretation. Additionally, in connection to this may also be stated that the method that has been used thus far in order to derive the propagation delay with respect to continuously distributed charges is inherited with a serious mathematical error [9]. The fundamental error, being replicated by Feynman [10] is that the charges are being counted twice, since the infinitesimal analysis of the electric currents, being regarded as continuously distributed charges, has been done erroneously. Also Wesley criticizes the method being used [11]. Wesley is attacking the analysis by Liénard and Wiechert for introducing a dependence of the retarded distance to a source point of action by the retarded time, but that criticism has been rejected due to mathematical deficiencies in his interpretation [12]. Leaving all these misinterpretations behind, the benefit of the new Coulomb law theory as interpreted by Jonson [8] is that it is also able to account for the longitudinal forces between collinear currents, which the Lorentz theory cannot. This disability to do both has impelled Graneau to try a compromise, in that he assumes the separate existence of both Lorentz forces and another longitudinal force that he calls 'mechanical force' [13]. The benefit of this approach is that he recognizes the possibility that there exists another force that cannot be understood within the realm of Lorentz' force law. However, it doesn't answer any questions. It is more a temporary, practical solution, waiting still for the explanation.

Graneau is speaking of a so-called "Ampere-Neumann electrodynamics" [1], though causing disagreement among others [14]. Making reference to the case of ruptures of wires, Lukyanov and Molokov claim that, contrary to Graneau, the

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induced flexural vibrations are strong enough to lead to the breaking of the wire. Instead of taking part for either of the different opinions on that specific issue, it could now be appropriate to turn to what Neumann himself is writing. He is namely the scientist, who is main responsible for the birth of the concept "Ampere-Neumann electrodynamics". In spite of that, Neumann [15] is also raising questions concerning the experimental basis behind the construction of Ampère's law. He says that there aren't any, but he accepts the situation, that Ampère's law has once been defined, and he makes an effort to prove that the electromotive force attained due to Lenz' law satisfies Ampère's law. This, as well as Maxwell's own expression of admiration for Ampère's law, without giving any proofs supporting the statement [2], point to what seems to be a very high level of authority of Ampère at the time. That makes it increasingly interesting to analyze the arguments of Neumann

Neumann makes an ad-hoc definition of the electromotive force (EMF) that he claims arises due to Lenz's law [16], using his own description. To be mentioned is that Neumann only analyzes one of the three cases of induction that Faraday defines, that in which there is a relative movement between a primary circuit carrying a current and a secondary loop [17], [18]. Fig. 1 is illustrating the situation, how Neumann thinks that a primary circuit affects a secondary circuit, giving rise to an electromotive force (emf).

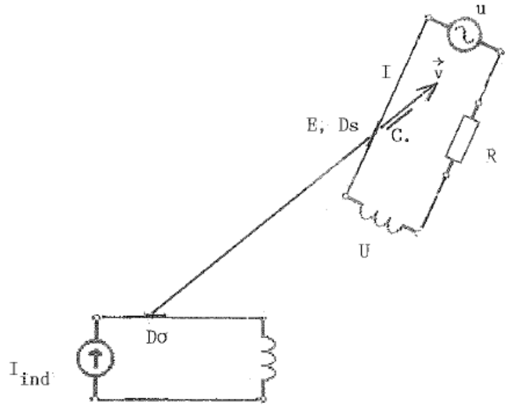

Fig. 1. Induction in a moving secondary circuit due to a primary circuit.

II. A Closer Look at the Neumann Method with Respect To AMPÈRE'S Law

Neumann begins his analysis by making reference to Lenz´s law [16], without making any precise reference. He just says that the expression for induction is

$$E.Ds = -\varepsilon v C.Ds \tag{1}$$

Please note the way Neumann indicates multiplication, through a dot at the bottom of the row.

However, he does not prove, how he attains the formula, maybe regarding it as self-evident, which is a fundamental problem if intending to verify the steps in the derivation of the force that he performs. Anyway, Lenz does not define this formula. Instead, he is only speaking of the direction the induced current of a secondary circuit will have with respect to the inducing current of a primary circuit [19]. Here Neumann also commits a fatal error, in that he confuses the electromotive force with a mechanical force, which becomes evident through the definition of the variable C as a mechanical force [16]. It becomes evident from the steps that follow. A citation makes this very clear: "We think of the arisen electromotive force as an accompanied result of the voltage that induction has given rise to." [20] Yet, the left hand expression of the equality has voltage/length unit as the variable, whereas the right hand expression has the electromotive force in the sense 'mechanical force'. However, the following expression for Lenz's law was found in a basic course book on electromagnetism [21]:

$$E = -\frac{\partial \Phi}{\partial t} \tag{2}$$

This indicates some of the confusion that reigns in connection with electromagnetic induction. Lenz' law is namely speaking of the direction of the induced current, not giving any expression for that [19].

$$\frac{dU}{ds} \tag{3}$$

When defining the induced electromotive force (emf), he uses emf per unit length, which is equivalent to speaking of the electric field. Accordingly, he writes thereby defining the induced voltage with opposite direction as the emf.

$$-\frac{dU}{ds}Ds = EDs \tag{4}$$

Here it again becomes evident that Neumann believes that the electromotive force (emf) is a mechanical force, though being a consequence of the voltage [22]. This is however not true, which already a rudimentary dimensional analysis reveals:

$$Dim(F) = Dim(P \bullet t) = Dim(V \bullet I \bullet t) \tag{5}$$

The electromotive force E above on the contrary has the dimension voltage/length

He thereafter derives the current, calling it 'flowing charge amount', by multiplying the left hand expression of (4) with the cross section q and the conductivity k , thus attaining

$$-qk\frac{dU}{ds} = qkE \tag{6}$$

which in turn is equal to the current that flows through the cross section.

In fact, this nothing short of than Ohm's law, i.e. a linear relationship between current and voltage, based on the conductivity, i.e. the inverse resistivity, involving no phase shift. This, however, must strongly be opposed, since it is usually supposed to be a 90 degrees phase shift between current and voltage in the case of induction.

One may as well use the letter I in order to express current, which is commonplace today:

$$I = -qk\frac{du}{ds} \tag{7}$$

$$I = jq \tag{8}$$

Thereafter, he introduces another voltage, also this one as a function of time and space, using instead lowercase. He namely claims that there already exists a voltage in the secondary circuit. This is the reason for having a voltage source applied to the secondary circuit in the figure. Using still the same interpretation of Ohm's law as in connection with (5), accordingly the current is in this case being written

$$-qk\frac{du}{ds}\cdot \tag{9}$$

In this connection it appears that Neumann apparently assumes that there already is a voltage u along the secondary circuit, independent of induction [22], whereas Faraday is only speaking of one voltage along the secondary circuit, one that dies out if there is no relative motion between the circuits [17].

Neumann now claims that he now claims the voltage increases with the amount due to the current that flows through the secondary circuit thanks to the voltage u along the part Ds of the conductor with the induced current and voltage. It is a peculiar result, additionally dimensionally wrong if it should equal u as he claims. If namely differentiating the current (expressed by him as a 'flowing amount of charges') with respect to an incremental length element, it is impossible to attain a voltage increase.

$$qk\frac{d^2u}{ds^2}Ds \tag{10}$$

He now suddenly claims, though not expressing that very clearly that in the case there is no current that has been inferred through electromagnetic induction to the secondary circuit from the primary one the voltage along the secondary circuit will change with time according to the differential equation.

$$\frac{du}{dt} = k\frac{d^2u}{ds^2} \tag{11}$$

Having precisely discussed that this result is due to the lack of induced current, he immediately begins speaking of 'the inferred (necessarily meaning induced) current'

$$I = qkE \tag{12}$$

which he claims is now increasing the increase in electric voltage with

$$-qk\frac{dE}{ds}Ds \tag{13}$$

(Apparently he is only meaning a first order 'increase' and with respect, which can be inferred from below). What he now does is extremely illogical: he uses the expression due to the case 'no inferred current' to the expression due to the case 'inferred current', attaining

$$\frac{du}{dt} = k\{\frac{d^2u}{ds^2} - \frac{dE}{ds}\} \tag{14}$$

However, he just continues; by analyzing the movement of the conductor carrying the induced current, he arrives at an expression for the angular momentum, which has been possible to him by understanding the emf as a mechanical force, otherwise it wouldn't have been possible.

Since Neumann is assuming that the electromotive force is related to the voltage as appears from (4) above, by integrating $\frac{dU}{ds}$ along the whole secondary circuit, and dividing by the resistance, he arrives at an expression for the induced current

$$I = -\varepsilon\varepsilon'\int vCDs \tag{15}$$

Again the problem becomes evident that Neumann assumes a linear, phase-free relationship between current and voltage i1n the case of induction. Behind is the vague formulation earlier in the article by Neumann [16] that the emf is varying slowly, which allows Ohm's law to be used.

Anyhow, Neumann thereafter is deriving the 'effect' (German: Wirkung) that the current has during the incremental time interval dt, denoting this the 'differential current' [23]:

$$D = -\varepsilon\varepsilon' dt\int vCDs \tag{16}$$

During the time interval between t_0 and t_1 the current will be denoted 'integral current':

$$J = -\varepsilon\varepsilon'\int_{t_0}^{t_1} dt\int vCDs \tag{17}$$

A comment: Neumann uses another sign for the integral without defined boarders in the above expressions, a kind of uppercase bold *S*, meaning an integral along the whole secondary circuit. The effort is here to keep as close as possible to the original text, even though one would prefer writing in another way.

Choosing the expression for the 'integral current', Neumann now is able to return to the mechanical force exerted by the primary circuit on the secondary by regarding the part of the expression that is equivalent to the emf, that is by multiplying with the resistance (or, equivalently by removing the inverse resistance ε'). He is also transforming from velocity to linear displacement by defining

$$v = \frac{dw}{dt} \tag{18}$$

so that one may rewrite the integral current as

$$J = -\varepsilon\varepsilon'\int_{w_0}^{w_1}\int CdwDs \tag{19}$$

Neumann now is regarding the term $\varepsilon CdwDs$ as the virtual angular momentum, which is possible if recognizing the product containing a distance and a force and a direction dependent factor C.

He thereafter derives a result, though not describing the steps that the loss of living force during the movement of the secondary circuit from w_0 to w_1 under the influence of the inducing current of the primary circuit will be:

$$2\varepsilon\varepsilon'\int_{t_0}^{t_1} dt \cdot (\int vCDs)^2 \tag{20}$$

A closer analysis of this expression reveals that it resembles an expression for the work that the electric effect being integrated during the studied time interval, provided the current of the secondary circuit could be expressed according to (12) and (17), even though the constant factor 2ε raises questions. However, Neumann does not follow this track. Instead he returns to the analysis of the 'differential current' and 'integral current'. The way that Neumann has derived the secondary current is already being questioned earlier in this paper. Anyhow, Neumann continues, regarding now the secondary circuit as being at rest, arrives at a result for the 'integral current' and 'differential current' that the primary circuit induces in the secondary one. His intention appears to be to show that the magnitude of the induced current does not depend on, which one of the primary circuit and the secondary circuit is regarded to be at rest with respect to the other, and he is successful to this extent [24]. He gives the re-defined currents prime signs. He arrives at the result [25]:

$$J' = -\varepsilon\varepsilon'\int_{w_0}^{w_1}\sum\{X_s d\xi + Y_s d\eta + Z_s d\zeta\}do \tag{21}$$

where ξ, η, ζ are the orthogonal projections of w and $X_s D\sigma, Y_s D\sigma, Z_s D\sigma$ are the orthogonal components of the force that the secondary circuit(regarded to be at rest) s is exerting on $D\sigma$.

In fact this expression is nothing short of the earlier expression that he arrived at by using the original description of movement [26].

Neumann continues, making reference to Ampère's law, the force between the currents of respective primary and secondary according to Ampère.

Neumann writes [25]:

$$R = \frac{j}{r^2}\{r\frac{D^2 r}{DsD\sigma} - \frac{1}{2}\frac{Dr}{Ds}\cdot\frac{Dr}{D\sigma}\} \tag{22}$$

where *R* denotes the action exerted from one current element to the other, assuming a unit current at the secondary circuit

Ampère himself writes it in the following way [27]: describing thus the force between two current elements, Later on he arrives at *n*=2 and *k*= - ½ (The equality added by this author for readability reasons).

$$R_A = -\frac{ii'dsds'}{r^n}(r\frac{d^2 r}{dsds'} + k\frac{dr}{ds}\cdot\frac{dr}{ds'}) \tag{23}$$

Hence, Neumann just writes the law, using other symbols. Thereafter he is differentiating Ampère's law and succeeds in showing that the 'integral current' and the differential current' may be written in terms of Ampère's law [28]:

$$J' = -\varepsilon\varepsilon'\int_{r_0}^{r_1}\sum\int RdrDsD\sigma \tag{24}$$

Hereby he has succeeded in creating a nominal link between his analysis of electromagnetic induction and Ampère's law. Ampère's law doesn't involve any velocity term, whereas induction does. Neumann succeeds in eliminating this problem by instead regarding the displacement that takes place during a time interval.

The fundamental argument against Neumann's derivation is, however, the illogical introduction of a mechanical force, where such a one does not exist.

Therefore, there is an urgent need for alternative explanation to electromagnetic induction.

III. An Alternative Model Explaining Electromagnetic Induction

Jonson has attained a more simplistic model capable of explaining electromagnetic induction. It is based on the usage of the Continuity Equation for Electric Charge Density and Current Density [29] and the expression for the electric displacement, assuming no polarization [30]. Further, Jonson has developed a new theory for electromagnetism, without introducing specific magnetic fields [8]. This altogether leads to the following equation (without the $\nabla \times \vec{H}$ term that is usually being used in the law that Jackson is calling Ampère's law [31], not to be confused with Ampère's (force) law treated in section II earlier in this paper) [27]

$$\vec{i} = -\frac{\partial \vec{D}}{\partial t} \tag{25}$$

Or, if one prefers to use currents and voltages:

$$I = -C\cdot\frac{\partial V}{\partial t} \tag{26}$$

This usually applies to capacitors, but inevitably this term has the dimension 'capacitance' even if one is dealing with induced currents. It may best be treated as a coupling constant in that case. It has been shown elsewhere [6], [7], [12] that this analysis applies to the induction of a current in a secondary circuit.

The basic assumption is that the AC voltage which is built up along a primary coil winding exists also in its vicinity and if a secondary coil winding is being situated there, it will give rise to an induced secondary current according to (26). This discovery was made in connection with related discoveries that revealed that there are no magnetic fields, only electric Coulomb fields [8] and, hence induction must be given a new explanation, omitting magnetic fields. Simultaneously, it was also found that the traditional interpretation of induction implies a phase error in measuring the voltage of the secondary circuit, whereas the new model succeeds in this respect [6], [12].

IV. Conclusions

After having given a review over an ensemble of often disparate assumptions, fallaciously performed mathematical proofs, arguments not supported by mathematical statements etc., the focus of the paper has been entered, to analyze Neumann's work on electromagnetic induction and his effort to make it to appear to be consistent with Ampère's law. He begins the derivation by defining Lenz' law, but he doesn't explain how he has attained it. One use to call this an 'ad-hoc definition'. Thereafter, he states that the electromotive force (emf) is a mechanical force, caused by the induced voltage, without telling how this occurs. Then he states there exist is two voltages in the secondary circuit, one being there independently of induction, the other caused by induction. He arrives at a differential equation for the first voltage of the two mentioned. A voltage increase and a differential equation that he arrives at are not being satisfactorily explained.

Most interesting is to follow his efforts to use his derivation of the induced current of the secondary circuit to connect to Ampère's law, since here the roots behind the term Neumann-Ampère electrodynamics are to be found. At first must be stated that already his assumption that he may use Ohm's law in the case of slowly varying currents is contrary to experience, since the very phenomenon of electromagnetic induction is based on the change with time pf the inducing current. Secondly, he thinks of a mechanical force coupling in the expression for the secondary currents, which is also false. Nonetheless, this is the basis for his effort to align the law of electromagnetic induction with Ampère's law. To conclude, what Neumann is stating concerning electromagnetic induction is to most parts wrong.

Instead, the method being introduced by Jonson is to be preferred. It is based on Coulomb's law, deepening only the analysis of propagation delay, applying thus the self-evident continuity Equation of Electric Charges. Due to the simplicity of Coulomb's law in its easiest interpretations and its well-verified facts concerning the forces between static electric charges it must basically be more reliable if succeeding in deducing consequences for more complicated cases than electrostatics. A much easier and simultaneously more comprehensive way to explain electromagnetic induction, using carefully explained steps in the derivation, has already been given by Jonson.

Appendix

Variables used by Neumann:

E	induced electromotive force (emf) per unit length
Ds	infinitesimal element of the secondary circuit
ds	infinitesimal element of the secondary circuit, used in the case of differentiation
$D\sigma$	infinitesimal element of the primary circuit
ε	a constant factor
ε'	inverse resistance of the secondary circuit
v	velocity of the conductor carrying the induced current
w	linear displacement of the secondary circuit
q	cross section
C	the force that the inducing circuit exerts on the conductor carrying the induced current, dependent of the direction, though not expressed how by Neumann
U	induced voltage in the secondary circuit
k	conductivity of the secondary circuit
I	induced current through the secondary circuit (this variable introduced by the author)
j	current density circuit (this variable introduced by the author)
D	induced differential current of the secondary circuit
D'	induced differential current of the secondary circuit, new view of the relative movement between the circuits
J	induced integral current of the secondary circuit
J'	induced integral current of the secondary circuit, new view of the relative movement between the circuits
ξ,η,ζ	the orthogonal projections of w
$X_s D\sigma, Y_s D\sigma, Z_s D\sigma$	the orthogonal components of the force that the secondary circuit(regarded to be at rest) s is exerting on $D\sigma$.
I_{ind}	inducing current of the primary circuit (this variable introduced by the author)
R	the action exerted from one current of magnitude 1 A to the other

Variables used by Ampère:

i	primary current
i'	secondary current
ds	infinitesimal element of the secondary circuit, definition by Ampère [27]
ds'	infinitesimal element of the primary circuit, definition by Ampère [27]
r	distance between two current elements
n	the power of r
k	a constant factor
	the action exerted from one current element of magnitude 1 A to the other (the variable applied also on Ampère's expressions)
R_A	the action exerted from one current element ds to another ds' (the variable R_A invented by this author in order to attain an equality)

A. Variables from other sources

E	in (2): electromotive force as interpreted by iHallén [21]
Φ	magnetic flux as interpreted by Hallén [21]
t	time
F	force (this variable introduced by the author)
P	electric effect (this variable introduced by the author)
V	voltage (this variable introduced by the author)
$\vec{i}$	current density of the secondary circuit
$\bar{D}$	electric displacement field
C	capacitance
$\vec{H}$	magnetic field

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Jan Olof Jonson has published several papers mainly on electromagnetism, beginning with a paper published by the Chinese Journal of Physics in 1997, entitled "The Magnetic Force Between Two Currents Explained Using Only Coulomb's Law in which it is proven that Coulomb's law," is able to account for the repulsive forces within Ampere's bridge, whereas the Lorentz force law is not. The latest paper was published in 2012 by the Open Access publishing company InTech, entitled "Ampère's Law Proved Not to Be Compatible with Grassmann's Force Law". A paper presenting a new photon model is published in the *Proc. IX International Scientific Conf.,* "Towards a Classical Explanation to the Stable Electron Paths around Nuclei and to Radiation in Connection with the De-Excitation of Excited Electrons", "Space, Time, Gravitation", Saint-Petersburg, Russia, 2004.