Review of: "Circuits, Currents, Kirchhoff, and Maxwell"

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Potential competing interests: No potential competing interests to declare.

The work presented in this manuscript is not related to any new physical discovery but reviewing the concept of the "whole current" in classical electrodynamics. The following are some critical comments on the manuscript-

(1) Comments on the abstract: "In a series circuit, the coupling in Kirchhoff's law makes the total current exactly equal everywhere at any time."-this statement falls under some assumptions and not a general one. "The Maxwell equations provide just the forces needed to move atomic charges so the total currents in Kirchhoff's law are equal for any mechanism of charge movement."- the connection this statement is trying to make is vague.

(2)The currents in the physical world are usually associated with the flow of particles or energy or heat etc. More fundamentally, currents are derived from a continuity equation due to the conservation of some symmetry in the Lagrangian. Although it seems the author might be interested in the total energy current rather than a charge current, as hinted in the statement "current of this sort—of charge with mass—is not enough, particularly in the vacuum between stars to explain electrodynamics", but this is never said explicitly in the manuscript.

(2)Kirchhoff's current law is not exact but assumes the steady state and often involves lumped element description of the circuit. It seems redundant when the author is repeatedly emphasizing this already-known description and comparing it with Maxwell's equations.

(3)$\vec{\nabla}.\vec{J}_{total} = 0$ is not the definition of something that is conserved in time; the total time derivative of a physical quantity must vanish. Also, the notion of the displacement current in Maxwell's equation is consistent with the continuity equation. Eq~5 statement is nothing but the continuity equation in disguise:

$$\vec{\nabla}.\vec{J}_{total} = \vec{\nabla}.\vec{J} + \epsilon_o \frac{\partial \vec{E}}{\partial t} = \vec{\nabla}.\vec{J} + \frac{\partial \rho}{\partial t} = 0$$

, which is indeed the local charge conservation equation. Now, $\vec{\nabla}.\vec{J} = 0$ simply tells that the total charge current $\int d\vec{S}.\vec{J}$, across the boundary of a finite region of space is zero when we assume a steady state.

(4)Apart from the above comments, some statements viz. " The charge that is a source of the electric field is not visible in steady state analysis"- needs proper explanation.