

Feature Article

Guiding the new era of electrified transportation with 4-networks 4-flows integration theory and practice

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1. Introduction

Mobility means freedom. Mobility is the most apt function in our quest for happiness.

Since the invention of automobiles over a century ago, vehicles have changed the world. Automobiles have promoted and still promote global economic development and improve human standard of living by enabling mobile freedom. The following figures review the development of electric transportation.

We are now facing abundant historical opportunities, such as the evolution from the fourth to the fifth industrial revolution and the advantages of the artificial intelligence (AI). While in practice, we experienced that only the AI is still not sufficient to solve the challenging complex issues. Thus, the fifth industrial revolution will focus on the fusion of human, AI and environment. In this context, the author published the White Paper on Industry Development Guided by 4-Networks 4-Flows Integration in December 2020, in which the 4-Networks refers to energy network, information network, transportation network and humanity network, the 4-Flows refers to energy flow, information flow, material flow and value flow. Energy network, information network and transportation network are the three pillars of the economic foundation, while the humanity network is the key component of the society's superstructure. Developing of the 4-Networks 4-Flows Integration is good for inspiring people's subjective activity to integrate the energy revolution, information revolution and transportation revolution, building the unique relationship of production based on



Figure 1: Horse carriage before the appearance of early electric vehicles in 1820, low speed, low efficiency, pollution



Thomas Parker and his electric car. 1884



Morris & Salom's electrobat. 1895



London Electrical Cab Company's taxi. 1897



New York City Taxi. 1901



Baker Electric Car. 1902



GE charging station with a Baker Electric in early 1900's



German electric car with the chauffeur on top 1904



Detroit Electric advertisement 1912



Thomas Edison and an electric car 1913

Figure 2: Early electric vehicles

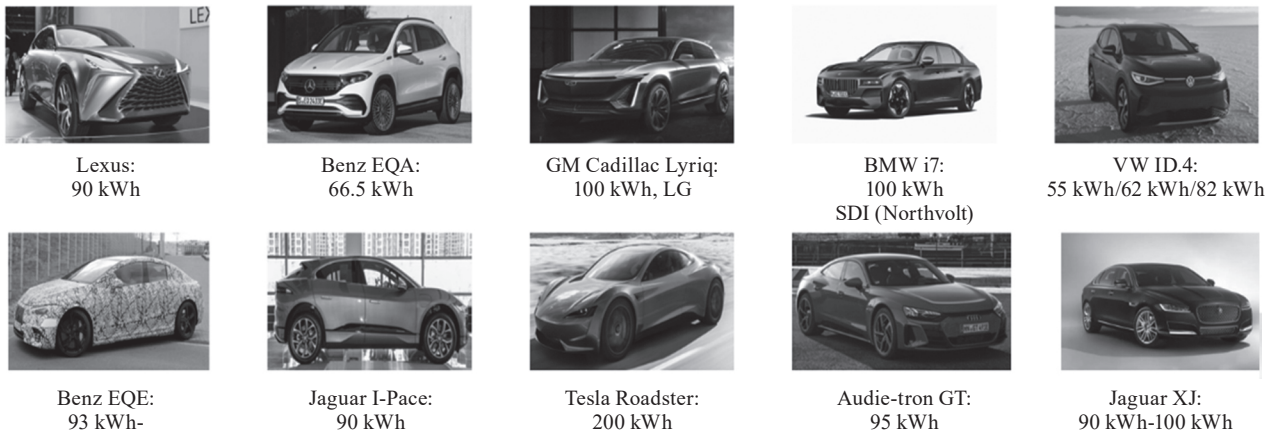


Figure 3: Top models of electric vehicles in 2022

human-cyber-physical system, as well as digging the digital bonus started from the 4th industrial revolution for the coming exponential increase in productivity. 4-Networks 4-Flows Integration Theory and Practice represent the fundamental change and influence on the people's way of thinking, from philosophy

to science to engineering. To philosophy of a holistic thinking - Whole is greater than the sum of each individual; Economic foundation interacts with superstructure. To science theory - It explored the fundamental relationship among energy, information and human behavior. To engineering - It combined the energy technology and information technology through a smart energy operating system, applying cloud technology, edge computation, artificial intelligence, big data technology, to achieve value-added results.

The coming new era of electrified transportation should be guided by the Theory and Practice of 4-Networks 4-Flows Integration. Through making full use of the digital productivity, we are able to develop the electrified transportation heading to a smart, low-carbon and sustainable way. This means that we should not just pay attention to the road side or transportation side, but devote to solve the multidimensional collaborative issue about human, transportation, infrastructure, and environ-



Figure 4: High speed train

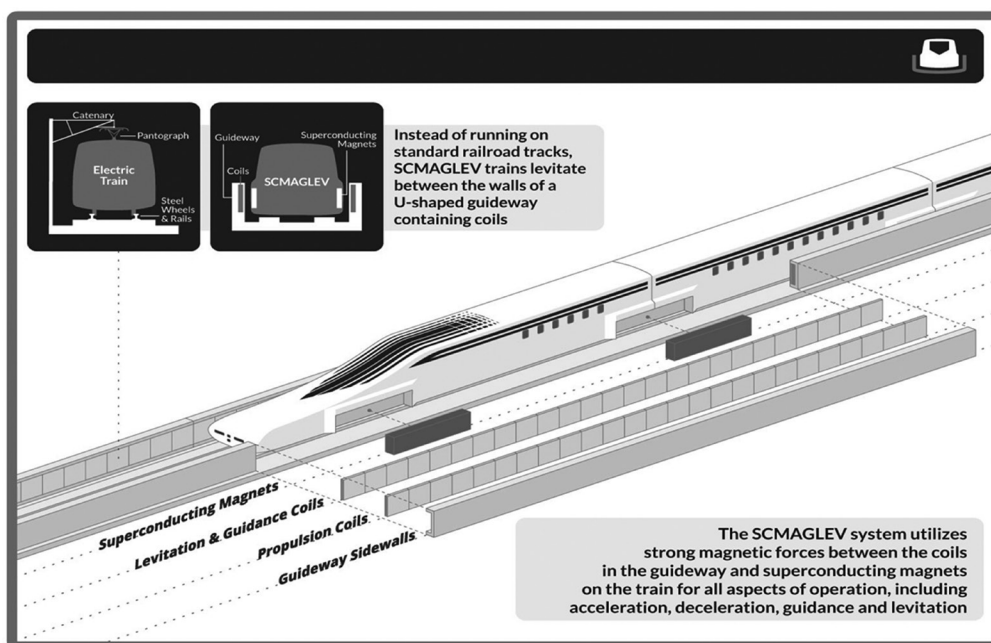


Figure 5: Maglev

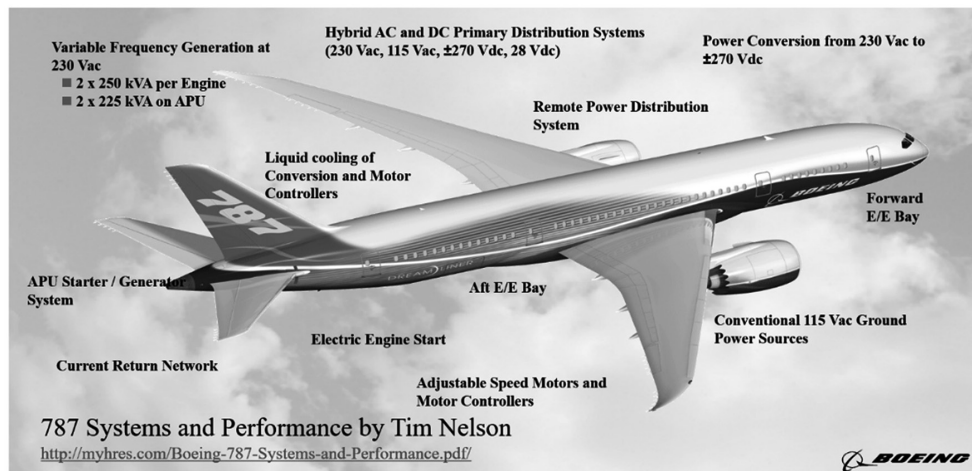


Figure 6: More electric aircraft

ment, hence to promote the sustainable development of our country, as well as human and natural life community.

2. “Human-cyber-physical” system and four networks

Currently, the energy network, information network and transportation network are the three pillars of the economic foundation. To form a superstructure, a humanistic network is needed and a new relationship is to be formed within the “Human-Cyber-Physical” system as illustrated in Figure 7.⁽¹⁾ The system links the Social, Cyber and Physical Worlds, embedding a correlation between energy, information and human behaviour.⁽²⁾ Therefore, the transportation revolution can be linked with the energy revolution and information revolution, as well as the smart energy⁽³⁾ can be linked with smart transportation. To develop a customized product and service, understanding of user behaviour, social pattern and culture impact is essential. To enhance Digital Productivity, a digital twin which models the object, process, organization and personnel can provide composite view (including hybrid elements) across real world entities. A cognitive twin is a related entity that can

process thought and acquire knowledge for solving related problems and issues.

The general definition of humanity refers to the advancement and core parts of human culture, including advanced values and custom. The rapid development of mobile internet and digital social network has fundamentally changed people’s lifestyles of shopping and socializing, forming a new type of “Consumer Humanistic Network”. Another new type is called “Industrial Humanistic Network” which is the advanced and core part of the industrial ecology including the business models and industrial standards in the industry. Driven by the Internet-of-Everything, the industrial humanistic network and the consumer humanistic network form a new digital humanistic network. This new production relationship between people, people-and-things and things-and-things under the Digital Economy is the key structure to pursuit Digital Productivity advancement.

In this Digital Economy, the Four Networks (energy network, information network, transportation network, humanity network) and Four Flows (energy flow, information flow,

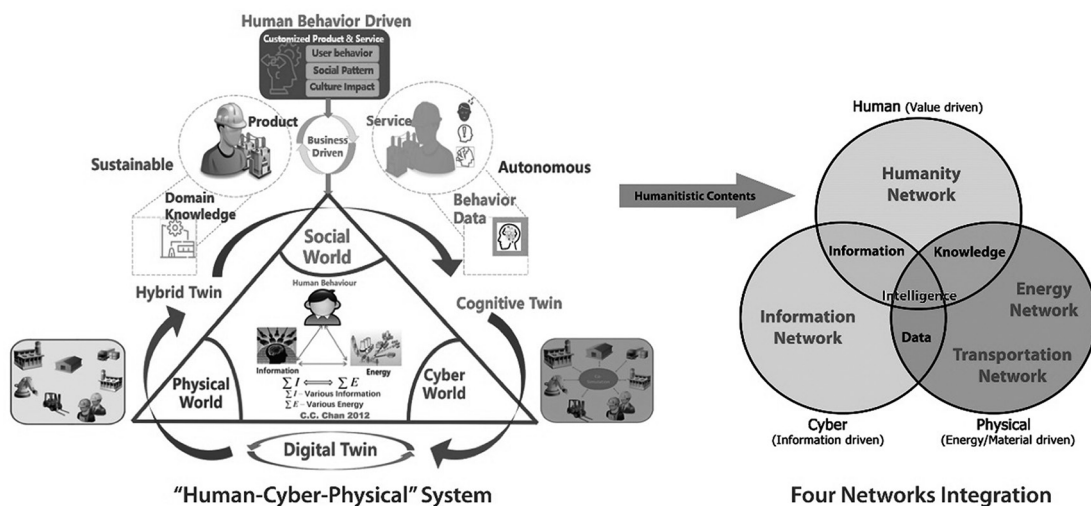


Figure 7: “Human-cyber-physical” system and four networks⁽¹⁾

material flow, value flow) for Industry Integration is shown in Figure 7. The interaction, namely the interactive integration, of these four networks can be represented by the corresponding flows between human, cyber and physical worlds. For the Industry Integration, digitalization is the direction and trend while transformation is the path and means; both are based on software and service-driven changes, which inevitably accompany the reshaping of production relations.

For the integration of human-information-energy-transportation, a new type of production relationship between human intelligence and machine intelligence can be established, thus it is possible to fully explore and release the huge productivity potential embedded in energy/transportation integration with an enhanced possibility of sustainable development.

For the integration of energy flow and material flow, a foundation for the establishment of a sustainable industrial ecology under the Digital Economy is essential. The goal of the Digital Economy is to continuously create new industrial value and accumulate huge social wealth through intelligence. It forms an industrial ecological joint innovation model through the interconnection of information flows between different industries and fields to maximize industrial value. Hence, the discovery of value requires the establishment of a new interconnection model of energy flow and material flow inside and outside the industry to minimize energy consumption and increase the utilization rate of material resources. Through the small data/big knowledge structure based on edge computing, the integration of decentralised clean energy/low-carbon transportation can reduce dependence on big data. The energy consumption requirements of data processing will ultimately be reduced to realise the sustainable application of artificial intelligence in the future. Through the integration of Four Networks, the technical specifications, domain knowledge, safety specifications and management standards, through semantic models, can be automatically transformed into a knowledge spectrum and a knowledge base. The key in this “Human-Cyber-Physical” system is intelligence.

3. Conclusion

The 4N4F concept promotes the development of smart energy, smart transportation and smart city. Energy as a Service is the integration of energy and information networks to provide Energy Internet to achieve Smart Energy. Mobility as a Service is the integration of energy, information and transportation network to provide Internet-of-Vehicles to achieve Smart Transportation. City as a Service is the integration of energy, information, transportation and humanity network to provide Digital Economy to achieve Smart City.

This article explains the fundamental theory and holistic concept between four networks & four flows which are highly correlated and their integration methodology can be applied to smart energy, smart transportation and smart city. The key discovery of the author is the correlation among human behaviour, energy and information hence the Human-Cyber-Physical

interaction. The 4N4F will significantly contribute to break through those constraints associated with energy, transportation and environment. It will also overcome the barrier for a seamless integration of mechanism models and data models, and advocate the key concept of “Human-Cyber-Physical” integration.

Notes

- ⁽¹⁾ White paper on 4 networks and 4 flows for industry integration development. Issued by China Institute of Communications, Chinese Society for Electrical Engineering, State Power Investment Co., Ltd., Huawei Technologies Co. Ltd. https://mp.weixin.qq.com/s/_FEU_DKL4L597e-mVbGCJw. (in Chinese)
- ⁽²⁾ Chan, C. C., Chan, F. C., and Tu, D. (2015). Energy and information correlation: Towards sustainable energy. *Journal of International Council on Electrical Engineering*, Vol. 5, No. 1, 29-33.
- ⁽³⁾ Zhou, G. Y., Chan, C. C., Zhang, D. et al. (2019). Smart energy evolution road-map based on the correlation between energy and information. *Energy Procedia*, Vol. 158, 3082-3087.