Innovation,
3 Revolutions, 4 Integration

Professor C. C. Chan

Academician, Chinese Academy of Engineering
Fellow, Royal Academy of Engineering, U.K.,
Co-Founder, World Electric Vehicles Association
INNOVATION DRIVEN
Freedom of Enquiry

The spirit of Raphael's School of Athens and the principle “I love my teacher, but trust the truth more”. 
Multi Dimensions Thinking

- **Holistic Thinking**
- **Mathematic Model & Big Data**
- **Causal & Related Relationships**
- **Closed Loop Thinking**
- **Cycle Thinking**
Engineering Philosophy

Objectives, Thought, Methodology, Implementation

Engineering = Science + Technology + Management

Experience & Practice

1) Objectives
2) Holistic Thinking
3) Creative Thinking
4) Divide and Conquer, Combine and Rule
5) Human Factors
6) Team Work
AUTOMOBILE REVOLUTION

- Electrification
- Intelligent
- Connected and Sharing
Mobility is Freedom.

Mobility is the most apt expression for our quest for happiness.
Historical Document Signed at EVS.9

Committing Support to Formation of World Electric Vehicle Association

MEMORANDUM SIGNED FOR WORLD ELECTRIC VEHICLE ASSOCIATION

Participants from: Top left: B. Fijalkowski (Poland), R. Atanassov (Bulgaria), H. Payot (France), C. Hayden (U.S.), Z. Feng (China), W.A. Adams (Canada), Bottom left: M. Chigioji (US), R. Lemberg (Australia), J. Lea (Korea), L. Secord (Canada), C.C. Chan (Hong Kong), F. Dierkens (A.V.E.R.E.), A. Aanathanakhri (India), T. Matsu (Japan). The above gentlemen signed the memorandum of agreement for the formation of a World Electric Vehicle Association during EVS.9 last November. Cliff Hayden (US), Ferdinand Dierkens (Europe) and Dr. C. Chan (Asia) have been appointed a steering committee.
Automobile Revolution

- Video Clip on Automobile Revolution
KEY TECHNOLOGIES

• Light Weight Body
• Integrated Power Train
• High Performance Safety Battery Pack
• Intelligent Charging
Core Proprietary Technologies - Light Weight

High Strength Steel Upbody

- Body strength is 60% higher than industry average
- Side impact door beams made of 2,000 mPa hot-formed steel with vanadium
- Lower costs of manufacturing and after-sales maintenance

Full Aluminum Underbody

- Full aluminum underbody with SPR and FDS joining technologies
- Curb weight reduced by 50kg

Curb Weight Comparison: C & D Class BEV SUV

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<thead>
<tr>
<th>Model</th>
<th>Curb Weight</th>
<th>NEDC Range</th>
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<tr>
<td>AIWAYS U5</td>
<td>1600KG</td>
<td>550km</td>
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<tr>
<td>TESLA MODEL X P100D</td>
<td>2600KG</td>
<td>550km</td>
</tr>
<tr>
<td>BYTON M-Byte</td>
<td>2000KG</td>
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<td>BYD Tang EV600</td>
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<tr>
<td>NIO ES6</td>
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Note: curb weight is for long range version

Confidential
Trend of electric drive system

- Higher System voltage
- Larger Power
- Higher power density
- Lower cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Platform</th>
<th>Power (kW)</th>
<th>Torque (Nm)</th>
<th>RPM</th>
<th>Ratio</th>
<th>Power Density</th>
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<td>2019</td>
<td>800V</td>
<td>150</td>
<td>20000</td>
<td>11</td>
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<tr>
<td>2020</td>
<td>800V</td>
<td>200</td>
<td>4500</td>
<td>11.8</td>
<td></td>
<td>2.0</td>
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<tr>
<td>2022</td>
<td>800V</td>
<td>250</td>
<td>5500</td>
<td>12</td>
<td></td>
<td>2.2</td>
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<td>2025</td>
<td>800V</td>
<td>300</td>
<td>6500</td>
<td>12</td>
<td></td>
<td>2.5</td>
</tr>
</tbody>
</table>

- 400V Platform (2019-2020):
  - 200kW; 4500Nm; 16000rpm; ratio 11.8; power density: Motor 4kW/kg; MCU 30kW/L
  - 250kW; 5500Nm; 18000rpm; ratio 12; power density: Motor 4.5kW/kg; MCU 30kW/L

- 800V scalable (2022-2025):
  - 300kW; 6500Nm; 20000rpm; ratio 12; power density: Motor 5kW/kg; MCU 45kW/L
  - 300kW; 6500Nm; 20000rpm; ratio 12; power density: Motor 5kW/kg; MCU 45kW/L

- ASM (220kW)
- EM+GB+MCU+PDU+OBC+DCDC (250kW)
Proprietary Technologies - Powertrain System

High Performance
Peak power of 170kW, torque up to 315Nm, max. speed of 16,000rpm

Smaller & Lighter
Integrated design and structure optimization allow weight reduction of 10%

Better NVH Performance
Better noise, vibration and harshness (NVH) performance with noise reduction up to 10% compared to similar products

Highly integrated Powertrain System
AIPT (from 2020)

Proprietary Battery Pack
AIBP (installed)

High Energy Density
Leading energy density up to 181wh/kg

Sandwich Structure
Sandwich structure design and high energy density for better performance and safety

Smart BMS
Battery monitor & analysis, Battery safety management, energy control management, battery information management

Confidential
Each vehicle with an electrified powertrain has different requirements that determine the development of the battery.

### KEY REQUIREMENTS PER BATTERY TYPE

<table>
<thead>
<tr>
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<th>48 V</th>
<th>(P)HEV</th>
<th>BEV</th>
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</thead>
<tbody>
<tr>
<td>High power density</td>
<td>Up to 30 kW (30 C)</td>
<td>Up to 200 kW (10C for PHEV 100 C for HEV)</td>
<td>Up to 600 kW (6 C)</td>
</tr>
<tr>
<td>High energy density</td>
<td>-</td>
<td>-</td>
<td>&gt; 200 Wh / kg</td>
</tr>
<tr>
<td>Fast charging</td>
<td>-</td>
<td>80% in 20 min (&lt;50 kW sufficient)</td>
<td>80% in &lt;20 min (up to 350 kW)</td>
</tr>
<tr>
<td>Minimum cost</td>
<td>&lt; 300 € / kWh</td>
<td>&lt; 160 € / kWh</td>
<td>&lt; 100 € / kWh</td>
</tr>
<tr>
<td>Modularity &amp; scalability</td>
<td>Tier-1 part Standard housing</td>
<td>Tailored design</td>
<td>Standard Modules &amp; Customized housing</td>
</tr>
</tbody>
</table>

Source: FEV
Worry-free Charging Solution – use the car like the phone

More than 503km (NEDC) mileage provide the worry-free driving

For charging, provide wall box for home charging, which support remote charging reservation on APP;

In some parking cluster area such as airport, hard to find enough charge station, charging robots will fill that gap.
Three Revolutions: 3R
- Energy Revolution
- Information Revolution
- Mobility Revolution

Four Networks: 4N
- Energy Network
- Information Network
- Transportation Network
- Humanity Network

Four Flows: 4F
- Energy Flow
- Information Flow
- Material Flow
- Value Flow
Three Revolutions and Four Integrations

- Energy Flow
- Information Flow
- Material Flow
- Value Flow

Through the integration of the **four networks**

- Energy Network
- Information Network
- Transportation Network
- Humanities Network

And the integration **four flows**

- Energy Flow
- Information Flow
- Material Flow
- Value Flow

To link **Energy Revolution, Information Revolution, and Mobility Revolution** to gain the largest effect.

**Integrating Philosophy, Science and Engineering.**
Philosophy and patterns of energy integration

What are 4 networks with 4 flows

Features and benefits of 4N4F

Vision of integration with 4N4F
The Philosophy, Science and Engineering of
the integrations of 4 Nets and 4 Flows

- **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 tech and information tech through a smart energy operating system already developed, with energy tech combined with cloud tech, edge computation, artificial intelligence, big data tech, to achieve value-added results.
**AI’s role as Human in 4th revolution**

- **First Generation**
  - Steam Engine
  - Late 1800s

- **Second Generation**
  - Power Energy
  - Early 2000s

- **Third Generation**
  - Digital Technology
  - Mid 2000s

- **Fourth Generation**
  - Artificial Intelligence
  - Early 2100s

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**What is the correlation nature between energy & information?**

**How do human behaviors drive the correlation into intelligence?**

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- 5G + AI has changed the interaction between Technology & Human

- Integration of key technologies with humanity is future trend

- 4 Network will merge into one

---

Energy & Information in the Nature

- **Energy/Materials**
  - Einstein’s Equation
    - $E = mc^2$
  - Entropy/Information
    - Shannon's Equation
      - $I = -\sum P \log P$

- Systems Retention Time (t)
  - $t = \frac{1}{\text{entropy}}$
  - Boltzmann Constant $k$, $T$
  - Temperature $T$

---

Human Behavior

\[
\sum I = \sum E
\]

- Various Information
- Various Energy

- C.C. Chan 2012
4N Trend of Energy Integration

- New Service
- New Experience
- New Market

The booming market from demanded services

Cloud / IoT

The emerging need for integration of 4 Networks

- Change of Energy Usage
- Change of Mobility
- Life-style Adaptation

Stages

Energy Service

Energy Internet

Smart Grid

2000 2010 2020

E- Energy  I- Information  T- Transportation  H- Humanity (behavior driven social network)
Patterns of Integration of 4N

Web Internet E-Commerce
1) Necessities
2) Individualized
3) High volume
4) Better deal

Mobile Internet Sharing Economy
1) Sharing Concept
2) Platform enabled
3) Mobile trading
4) C2C ready

5G+ IoT+AI
X as a Service (XaaS)
1) Energy as a Service
2) Mobility as a Service
3) Block-Chain Ready
4) Universal for all

Human Behavior is the fundamental data source for E-commerce

Fragmented idle resources (entropy) is reorganized with added values (exergy)

Integrated Planning Integrated Application

E-net + T-net + I-net → T-net + I-net + E-net

Integration of Four Network

1) Sharing Concept
2) Platform enabled
3) Mobile trading
4) C2C ready

Energy as a Service
Mobility as a Service
Block-Chain Ready
Universal for all

Integration of Four Network is the key for XaaS
Philosophy and patterns of energy integration

What are 4 networks with 4 flows

Features & benefits of 4N4F

Vision of integration with 4N4F
Integration of Four Networks

Energy

Transportation

Information

Humanity

All-in-one

Life, Work, Travel, Low Carbon, Environment Friendly, Comfortable, Convenient, Healthy, Intelligent, Happy.
Solve four contradictions: contradiction of new energy and fossil energy, contradiction of primary energy and secondary energy, contradiction of centralized energy and distributed energy, contradiction of electrical energy and chemical energy. Coupling optimization for different energy sources will make the waste energy become useful, meanwhile achieve the carbon balance.
Intelligent energy driven by 4N4F

4F Principle:
- Energy Flow
- Information Flow
- Material Flow
- Value Flow

- Use 4-Flow principle
- Overcome 4 key conflicts

Energy Internet
Coupling of E-flow & M-flow
Carbon Neutral Smart Energy Eco-system
Interaction features between 4N & 4F

**Digitization Cross-Industry X as a Service**

- IoT/Edge Computing
- Big Data/Cloud
- Electrification
- Charging/H2 refueling

**Transportation Network**
- H2 vehicle
- Energy changes Power of Mobility
- Information changes Control of Mobility
- AI changes Concept of Mobility

**Energy Network**

- VPP Virtual Power Plant
- Demand Response
- Energy Blockchain
- Micro-grid

**Humanity Network**

- Behavior driven / P2P sharing
- Technologies change Behaviors
- Behaviors change Values
- Values change Cultures

**E-Flow** — Energy Flow
**I-Flow** — Information Flow
**M-Flow** — Material Flow
**V-Flow** — Value Flow

• 5G changes Network
• IoT changes inter-connection
• AI brings potentials of data
Five key elements among 4N4F

- **Data** --------------- Un-structured (Internet) & structured (IoT)
- **Algorithm** ---------- Physical Model & Data Model
- **Computing Power** ---- Cloud & Edge
- **Platform** ------------ Operating System & App market
- **Openness** ------------ Open Eco-system & Sharing under Block-chain
- Philosophy and patterns of energy integration
- What are 4 networks with 4 flows
- Features & benefits of 4N4F
- Vision of integration with 4N4F
4N4F for energy transition

- 4-Flow integration is the principle of 4N4F across technology & economy
- 4-Network integration is the engineering implementation of 4N4F
- 4F4N is with global thinking so that it is better than added functions

4N4F brings out potentials of 4th industrial revolution
Benefits of 4N4F

- Entropy Increase from Energy Loss can be stored for later use
- Entropy Increase from Values Loss can be re-directed for added value
- Both scenarios can be tokenized for trading under P2P mechanism
Evolution Layer of 4N4F

- Meet Personalized need with service accuracy
- Build data analytics from user’s own experience
- Promote culture of shared economy for customers
- Study humanity pattern for better energy service

Key Driver: Big Data Profile of participants created from **personalized footprint**
Carrier and Network of 4N4F

Control method: $ds \leq 0$

Strategy: Entropy minimization

- Orderly
- Self-organizing
- Intelligent System

Entropy Reduction
Philosophy and patterns of energy integration

What are 4 networks with 4 flows

Features & benefits of 4N4F

Vision of integration with 4N4F
Vision of Smart City

4N4F brings out potentials for X as a Service for Smart City
• Technology ---- Energy as a Service & Mobility as a Service
• Culture ---------- Behavior as a Service & Sharing as a Service
4N4F is driving interaction between AI enabled technology with Human
- 4N4F integrate Energy & Transportation with AI into human life
- 4N4F enable culturization of AI-ready society towards digital economy
Inspiration
Imagination
Innovation
Integration
Implementation
Investment
The 34th World Electric Vehicle Symposium & Exhibition

Theme: Towards Intelligent E-Mobility

Venue: Air-hub Exhibition & Event Town, Nanjing, China

Date: 25 - 28, June 2021
the Topics:

A Electric vehicle and transportation system
Passenger cars, including pure electric, hybrid, plug-in hybrid and fuel cells;
Commercial vehicles, including pure electric, hybrid, plug-in hybrid and fuel cells;
Small cars, including electric two- and three-wheeled cars;
Public transportation, including buses and railways;
Shared and autonomous transportation applications;
Other vehicle technologies and applications, such as flying cars.

B Power battery and fuel cell
High-performance batteries, capacitors and other energy storage components and energy management systems;
Fuel cell and its system.

C Electric drive technology
Motor design for EV application, multi-physics simulation and digital twin technology;
Novel EV motors topology for EV application;
Power electronic device packaging and drive technology, including Si-based IGBTs and SiC MOSFETs;
High temperature passive devices and their packaging;
Power electronics topology and control for EV application;
Intelligent motor control and health status management;
Electromagnetic compatibility technology;
Test methods and test techniques;
Powertrain Integration.

D Charging/fueling infrastructure
Smart charging and V2G;
Hydrogen fueling infrastructure;
Standardization and interoperability of charging/fueling;
Wireless charging infrastructure (static and dynamic);
Case study on infrastructure deployment;
Fees, standardization and services;
Smart grid, micro-grid, charging network and smart home.

E Connection of power grid, power supply and vehicle
Demand management;
Automotive batteries in energy storage;
Grid implications of DC fast charging and ultra-high speed charging;
Advancements in V2G, V2X and connectivity;
Utilities project deployment case study;
Public policies and strategies for electric vehicle charging.

F Market
Domestic and global market development strategy;
Consumer needs, education, training, demonstration and motivation analysis;
City market case and demonstration.

G Policy
National and international electric vehicle development policies;
National initiatives;
Local and regional partnerships;
Case study of government project deployment;
Standards and regulations.

H Environmental, Energy and Social Assessment
Environmental benefits of electric vehicles;
Supply chain analysis: materials, manufacturing, recycling and reuse;
Energy security;
Analysis of the social impact of electric vehicles;
Hydrogen and sustainable energy;
Safety.

I Emerging Technologies
Smart Connected EV Outlook;
Integration of Transportation Network, Energy Network, Information Network and Humanities Network.
the Important Dates:
Call for Abstract Opens: 27 Aug 2020
Deadline for Abstract Submission: 9 Nov 2020
Abstract Acceptance and attendance Notification: 15 Dec 2020
Abstract Acceptance Registration and Payment Close: 15 Mar 2021
Deadline for Full Paper Submission: 10 Apr 2021

Website: www.evs34.org.cn