能源领域中的信息物理社会系统 (CPSSE)：对“智能电网 + 电力物联网”的诠释

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坚强智能电网＋泛在电力物联网

- 国网公司寇伟董事长在2019年工作报告中提出：
  - 一方面，持之以恒地建设运营好坚强的智能电网（SG）
  - 另一方面，实现万物互联的泛在的电力（能源）物联网（IoTE）

智能电网	＋	电力物联网	＝	两网融合发展的目标
Smart Grids		Internet of Things in Energy		技术概念与框架是什么？

内网-授权等措施保证了信息安全性，但也限制了开放性

可靠性与开放性两者协同的桥梁

能源转型要求分布能源与公众的广泛参与，充分的开放性

兼蓄两者——内网安全性与公网开放性

- 电力物联网（IoTE）是在智能电网（SG）多年实践后提出的新概念
  - 共同点：信息系统与物理系统的深度融合，以提升系统的经济性及可靠性
- 既然是新旧不同的概念，就必然存在明确的区别及功能上的分类准则
  - 两网不是简单的替代或备份，故 IoTE 的功能不应该与 SG 大量重复
  - 若不能明确区分两张网的功能，就难以顺利地建设与运营两网
  - SG 由工业内网支撑，只能接入信息安全有保证的那些终端，因此开放性很差
  - IoTE 由专用网支撑，并通过与互联网间的安全接口而具有开放性，同时又通过与内网间的安全接口与 SG 交互，从而使两网的融合兼备安全性与开放性
- 使能源系统能在信息安全的前提下向社会终端提供应有的知情权及参与权
- 既然 IoTE以高开放性区别于信息源较安全的 SG，其任务也应按之划分
  - SG 采集的数据来自信息安全性好的厂站内部物体及授权人员；IoTE 则必须采集那些信息安全性达不到要求的厂站外部物体及非授权人员的数据
  - SG 采用安全性高的工业内网，而 IoTE 则必须接受公用网的数据，在非授权数据引入的风险得到控制后才能接入专用网，后者再经过安全接口与内网交互
  - 需要建立一致的技术概念及统一的框架
- 公用网与专用网之间，专用网与内网之间的安全接口是两网融合的瓶颈

据此，汇报以下三方面的内容

一．两网融合的意义

二．两网融合的内涵

三．建议试点的案例

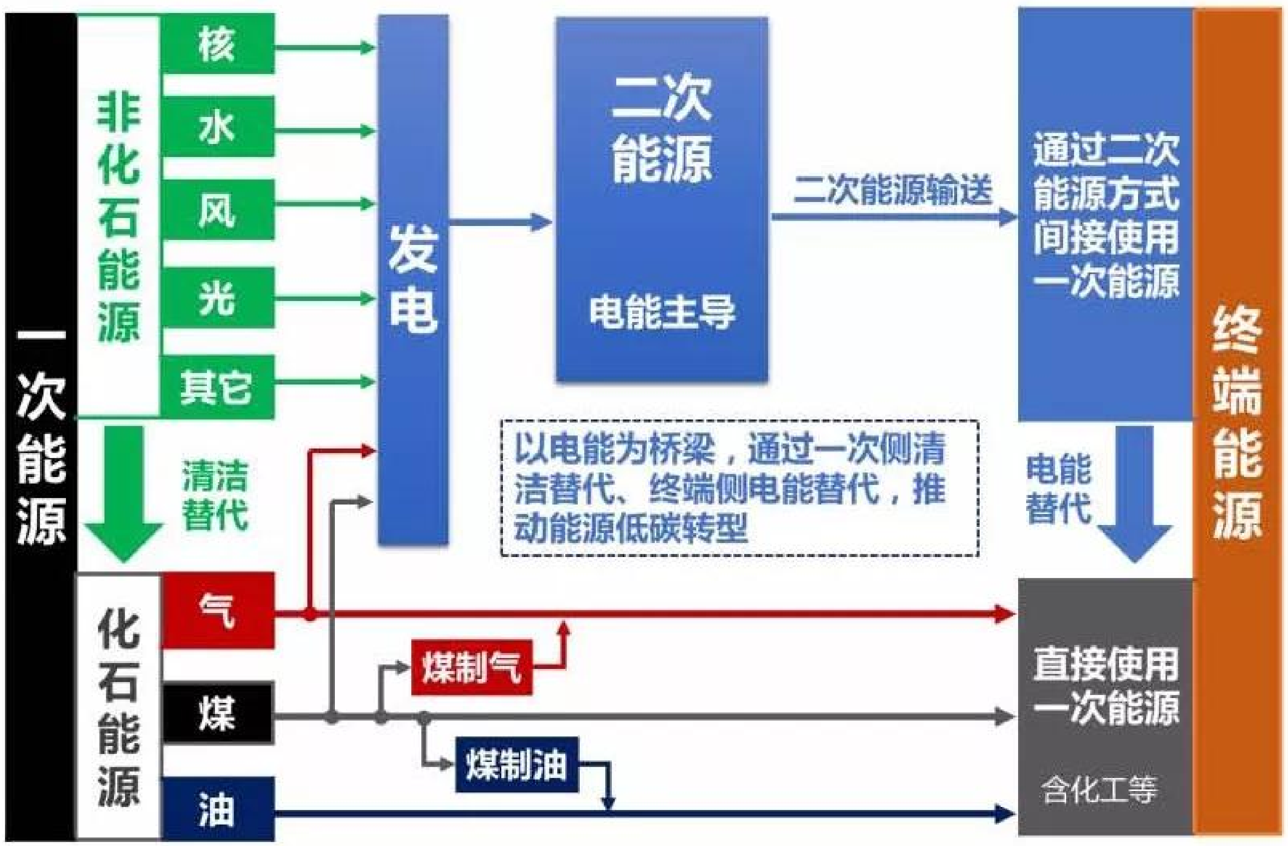
汇报内容

一. 两网融合的意义

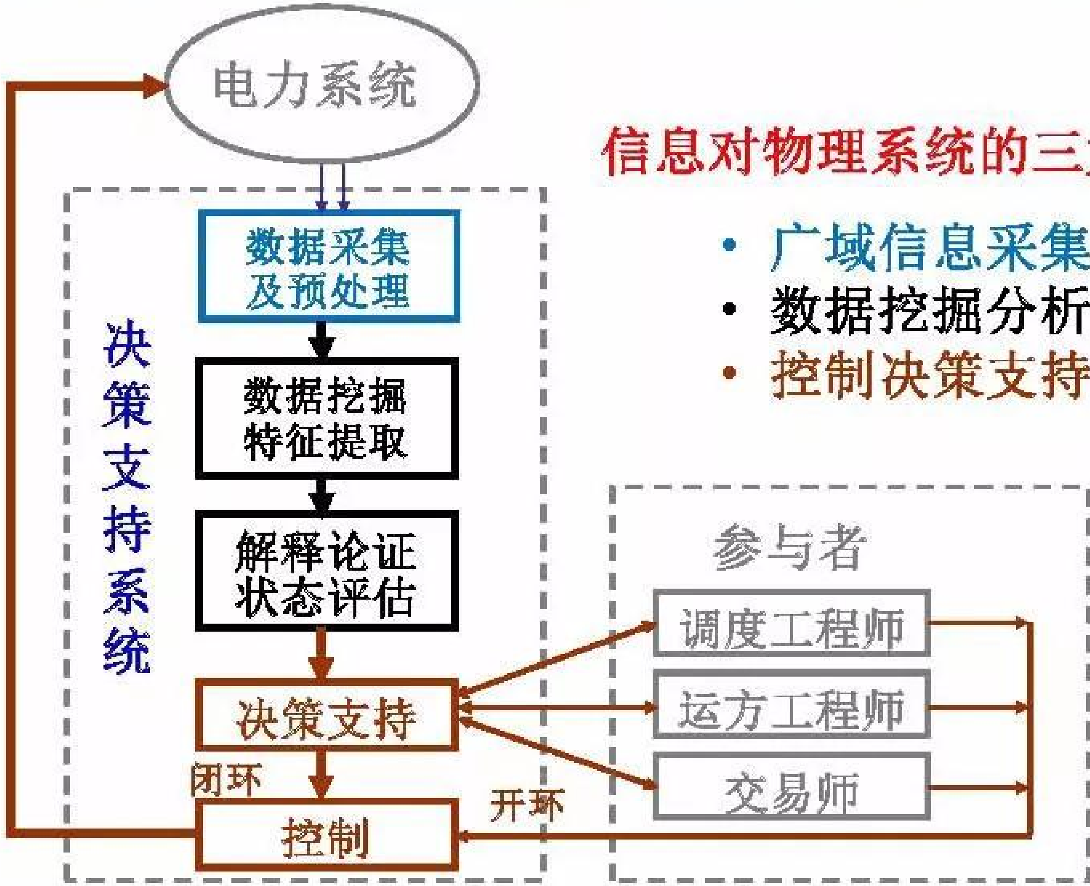
二. 两网融合的内涵

三. 建议试点的案例

必须保证整个能源链的可靠性，才有可靠的电力



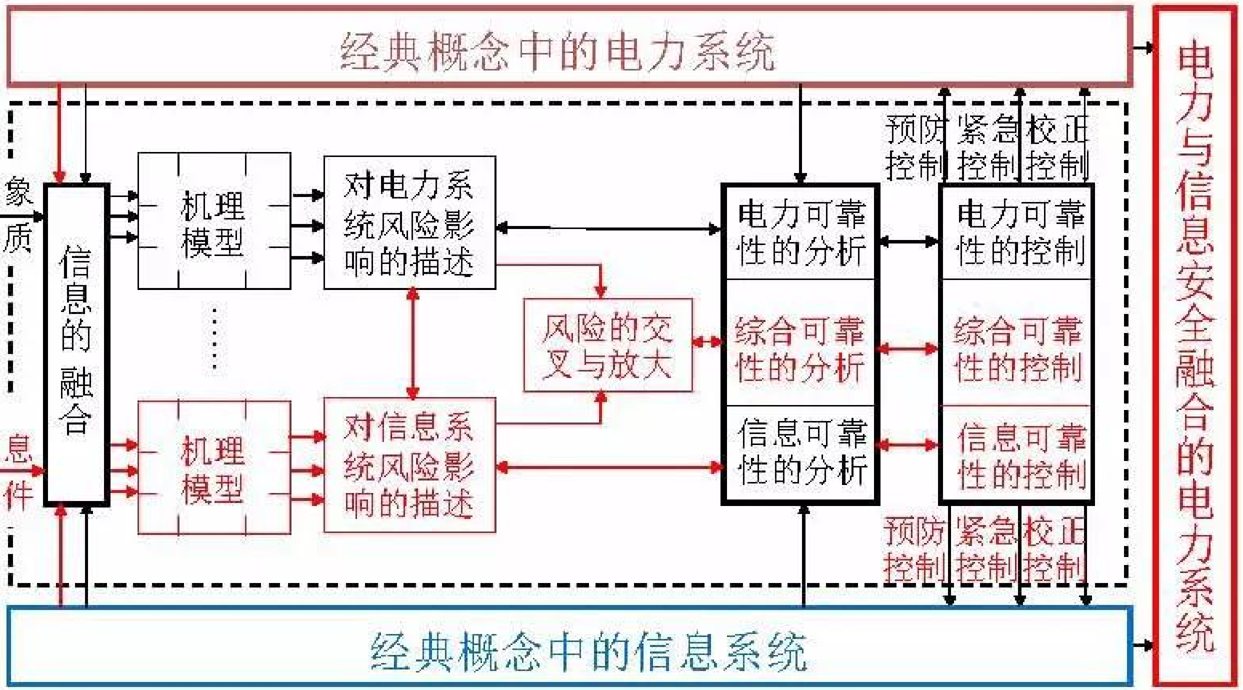
智能电网针对的仅是能源链中的电力系统



信息对物理系统的三大支持

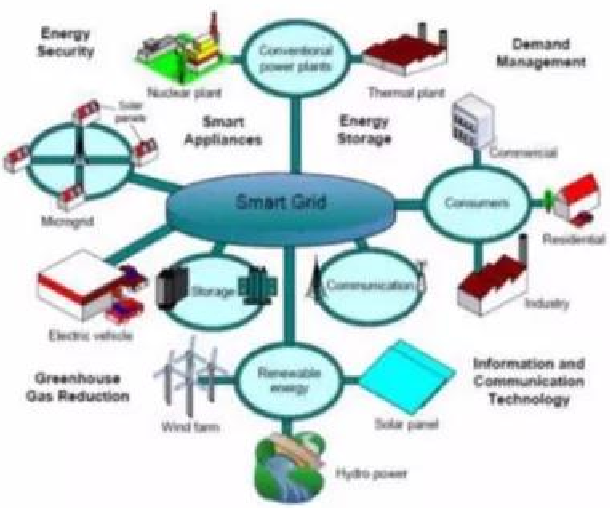
- 广域信息采集
- 数据挖掘分析
- 控制决策支持

信息与物理系统必须深度融合



2016年应邀发表在 PIEEE (IF=9.237) 上的文章指出：智能电网就是能源领域的 CPS

2 年半内已成为 高被引论文（141次）



INVITED PAPER

Smart Grids: A Cyber–Physical Systems Perspective

By Xinghuo Yu, *Fellow IEEE*, and Yusheng Xue, *Member IEEE*

ABSTRACT | Smart grids are electric networks that employ advanced monitoring, control, and communication technologies to deliver reliable and secure energy supply, enhance operation efficiency for generators and distributors, and provide flexible choices for prosumers. Smart grids are a combination of complex physical network systems and cyber systems that face many technological challenges. In this paper, we will first present an overview of these challenges in the context of cyber-physical systems. We will then outline potential contributions that cyber-physical systems can make to smart grids, as well as the challenges that smart grids present to cyber-physical systems research. Finally, implications of current technological advances to smart grids are outlined.

KEYWORDS | Big data; cloud computing; complex networks; control; cyber-physical systems; intelligent systems; modeling; multiagent systems; optimization; renewable energy; smart grid

I. INTRODUCTION

The greatest discovery of the 19th century was that of electricity which has led to revolutionary progression in our society and economy. Electricity became a fundamental form of energy carrier easier to transmit over long distance than any other form, and it has become essential to our social and economic activities. The electric grids, which are essentially massive interconnected physical networks, are the infrastructure backbone for energy supply and use of today [1].

In recent years, there have been increasing demands for cleaner energy generation and more efficient use of energy due to environmental concerns as well as limited availability of nonrenewable energy sources such as coal, gas, and oil. The 2014 World Energy Outlook Report [2] indicates that the global energy demand is set to grow by 37% by 2040, and energy efficiency is critical to relieve pressure on energy supply while accommodating increasing demands without severing the environments. While renewable energy (RE) sources such as hydro, biomass, solar, geothermal, and wind are in abundance, they are much harder to harvest. Advanced technologies are needed in order to make these energy supplies more reliable and secure. Internationally, governments of many countries have adopted/are adopting new energy policies and incentives, and larger scale deployments of smart technologies are now in place. In the United States, the all-of-the-above energy strategy has been launched by President Obama. RE generation from wind, solar, and geothermal sources has doubled since 2008, and a 20% RE target by 2020 has been set [3]. In Europe, a 20% RE target by 2020 has also been set by the European Commission [4]. In China, a 15% RE target was set to achieve by 2020 [5], and an even more ambitious target of 86% RE by 2050 has just been set by the Chinese Government [6].

All the above require a revolutionary rethinking of how to supply and use electric energy in a more efficient, effective, economical, and environmentally sustainable way. Smart grids (SGs) are such a new paradigm for energy supply and use in response to the aforementioned challenges. They aim to intelligently integrate the behaviors and actions of all the stakeholders in the energy supply chain to efficiently deliver sustainable, economic, and secure electric energy, and ensure economical and environmentally sustainable use. Key to the success of SGs is the seamless integration and interaction of the power network infrastructure as the

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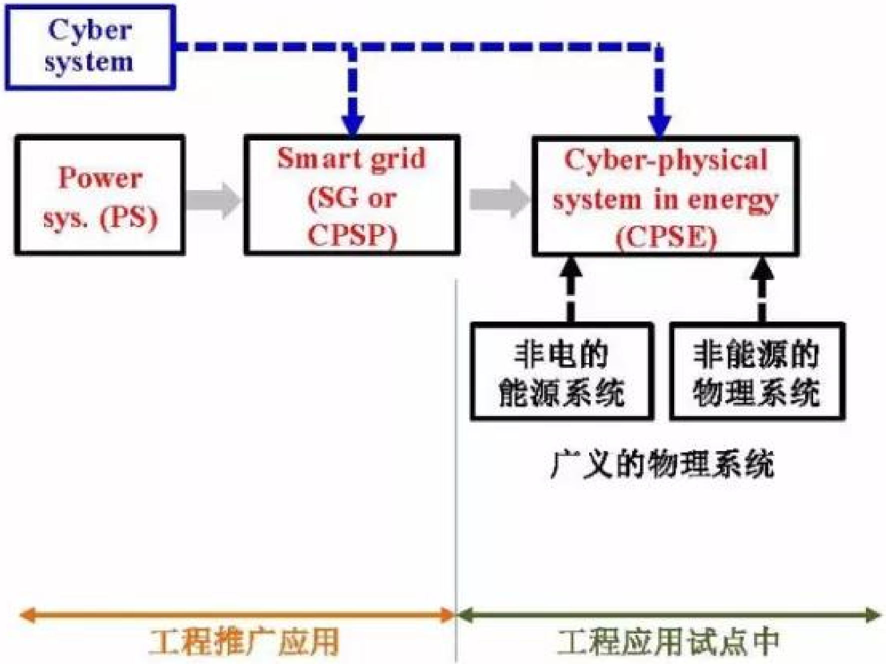
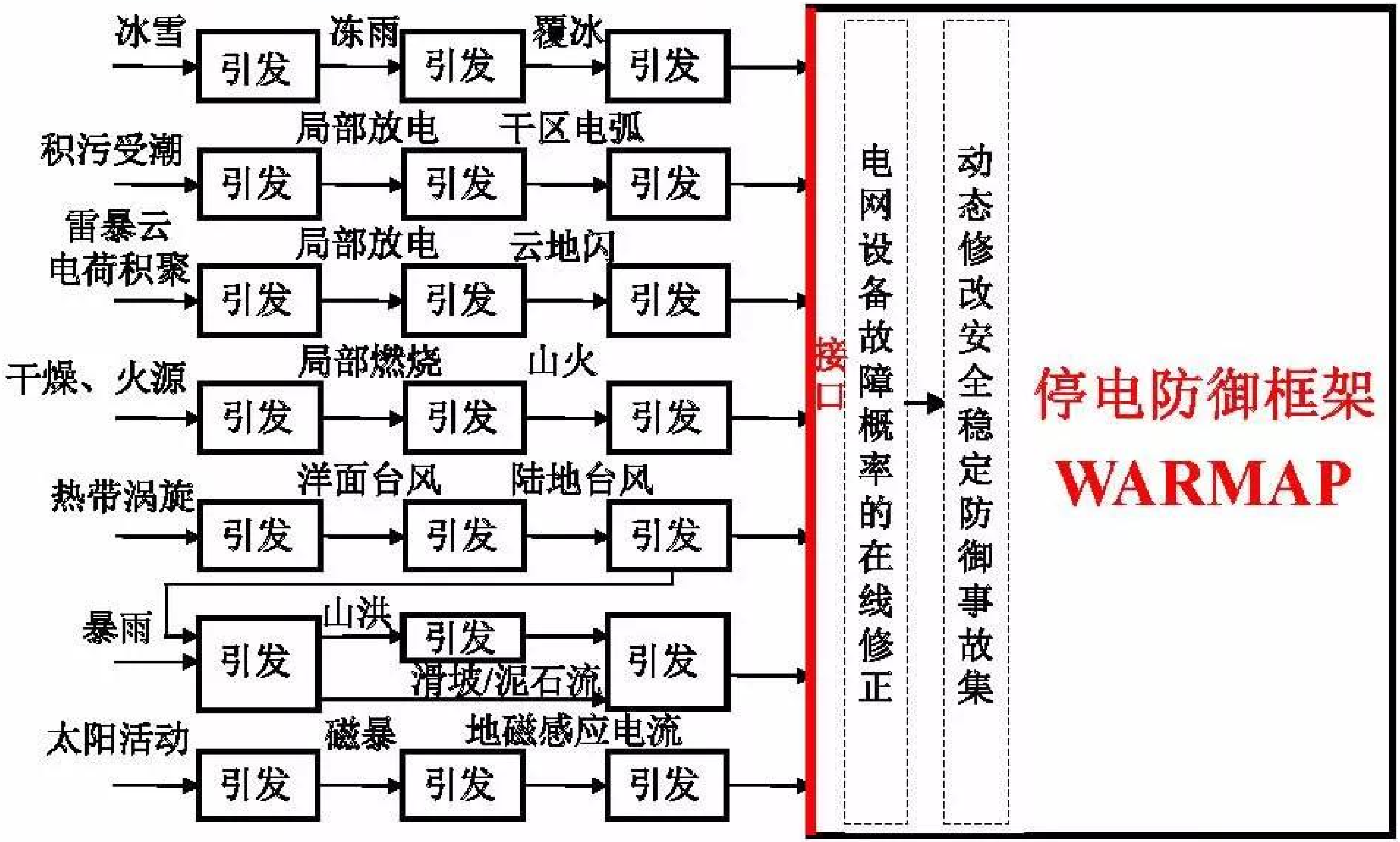
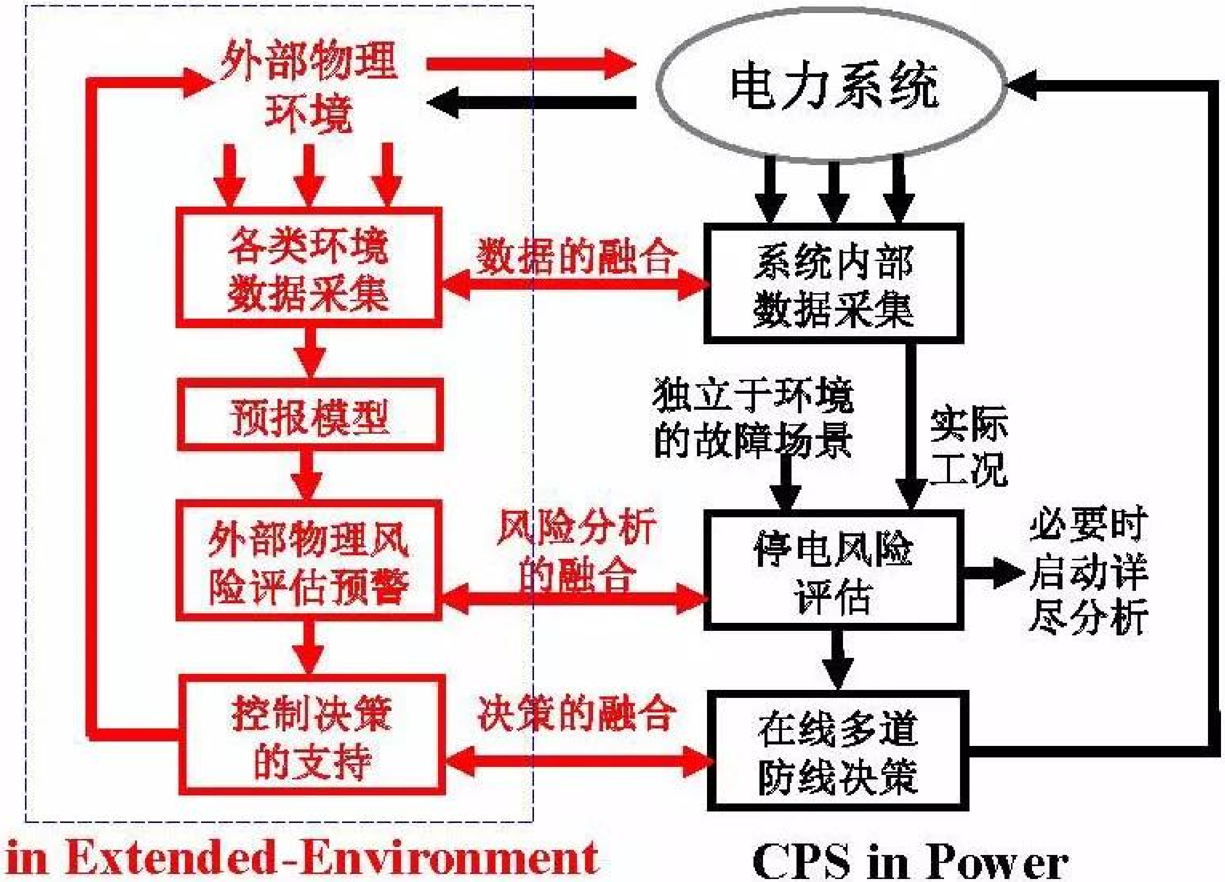
因此，CPSP 需要扩展到覆盖整个能源链及相关物理环境（CPSE）



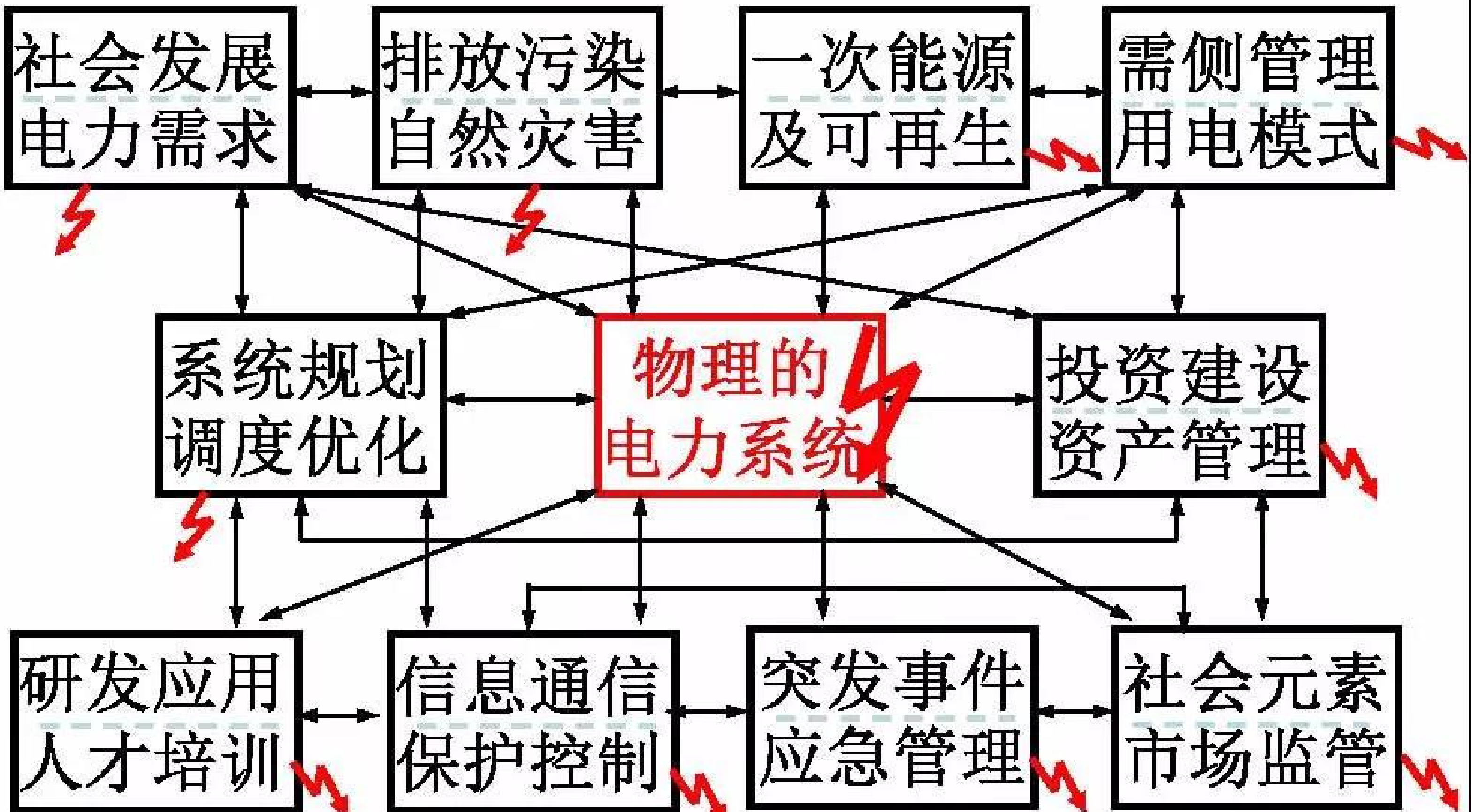
灾害的防御要将监控扩展到能源外的物理环节



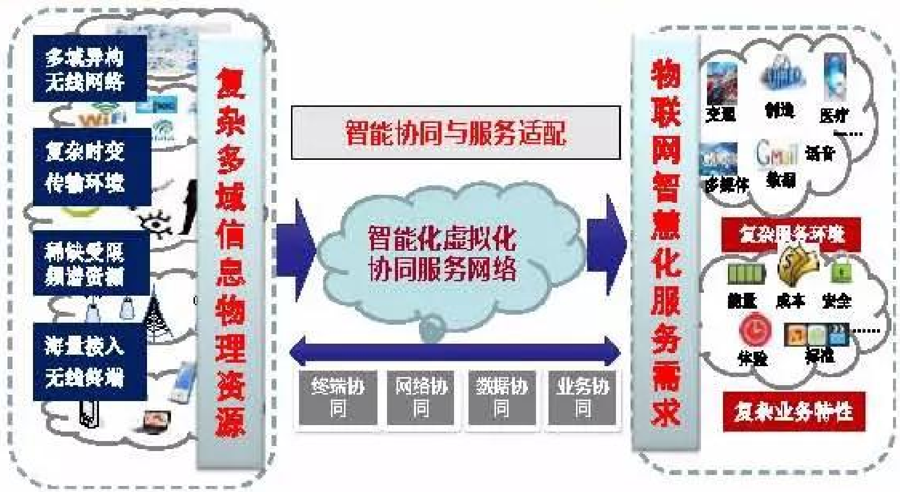
对物理环境具有自适应的CPSE 已逐步在工程中实施



然而，还有大量安全性不高的数据源需要被考虑



例如，SG 并未涉及移动物体及抢险资源的监控
—— 这些数据源的安全风险达不到 SG 的准入标准



又如，SG 并未涉及社会元素与能源系统间的交互

- 能源系统对社会的影响
  - 电力系统对非电力的能源环节、非能源环节，及社会的影响
  - 拓展需求侧的信息采集、知识挖掘、决策优化
  - 为不同用户优化其用电、用能方案，提供定制服务
  - 理解参与者的行为，建立模型，就近提供边缘计算
  - 需求侧的精准控制、恢复控制、间接价值和停电损失
- 社会因素对能源系统的影响
  - 政策与监管的不确定性对系统发展及运行的影响
  - 博弈行为及攻击行为对能源可靠性的影响
  - 拓展对环境、排放、市场等非能源信息的采集与处理
  - 对救灾抢修队伍及物资的智能调度
  - 需要将综合能源网从信息化发展为智能化