Digital Twin for Power Plants, Energy Savings and other Complex Engineering Systems

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Abstract

Digital Twin (DT) is a digital representation of a machine, service, or production system that consists of models, information, and data used to characterize properties, conditions, and behavior of the system. Renewable energy integration will make future power plants more complex with addition of varieties of Power-to-X technologies, Electrolysis to green hydrogen, onsite storage and transport of hydrogen, and use of pure or blended hydrogen, etc. These future power plants need robust DT architecture to achieve high Reliability, Availability and Maintainability at lower cost.

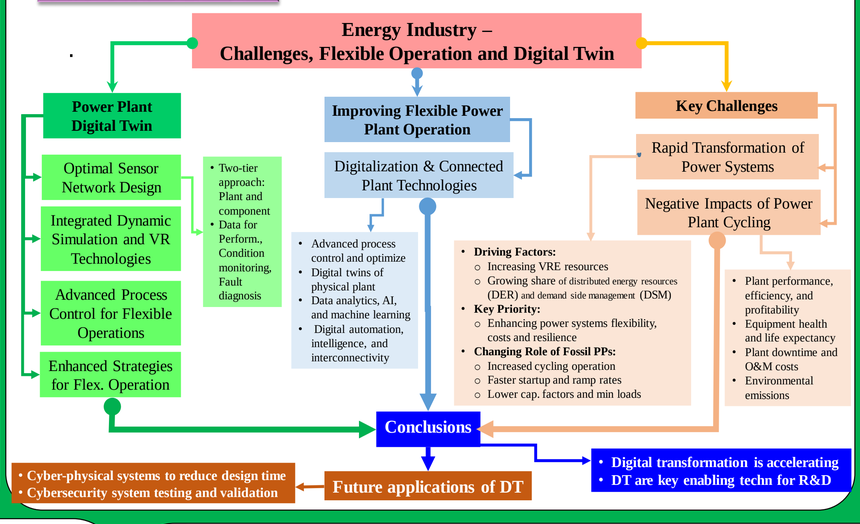
In this research work, a comprehensive and robust DT architecture for power plants is proposed that also can be implemented in other similar complex capital-intensive large engineering systems. The novelty and advantages of the proposed DT is asserted by reviewing the state-of-the-art of DT in energy industries and its potential to transform these industries. Then the proposed DT architecture and its five components are explained and discussed. More specifically, the main contributions of the present work:

i. Overview of DT key research and development for energy savings applications to consider important findings, research gaps and the needed future development for the proposed DT for power plants.

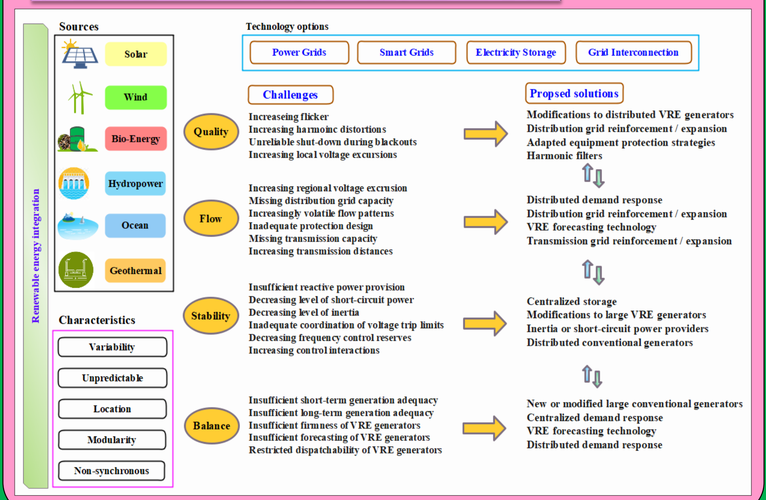
ii. Overview of DT key research for power plants including applications, frameworks and architectures to consider important findings and to confirm the novelty and robustness of the proposed DT.

iii. Proposing and demonstrating new robust DT architecture for power plants and other similar complex capital-intensive large engineering systems.

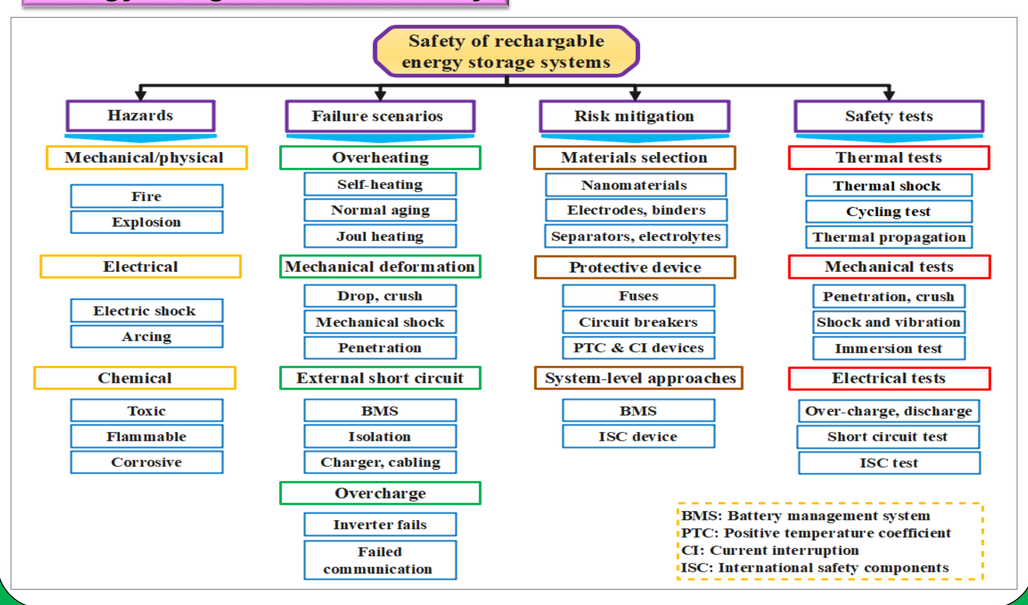
Introduction



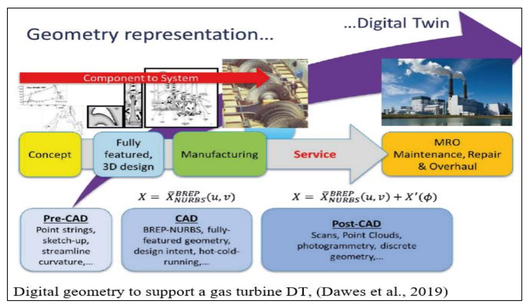
Renewable Energy Integration



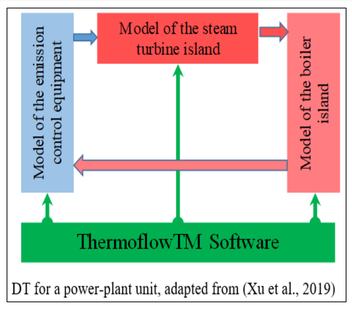
Energy Integration and Safety



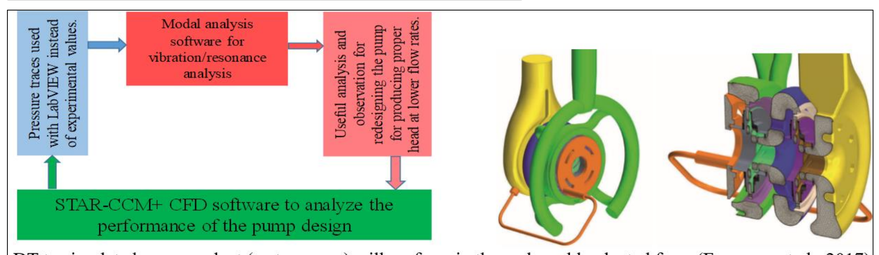
Digital twin for power plants and turbomachinery components



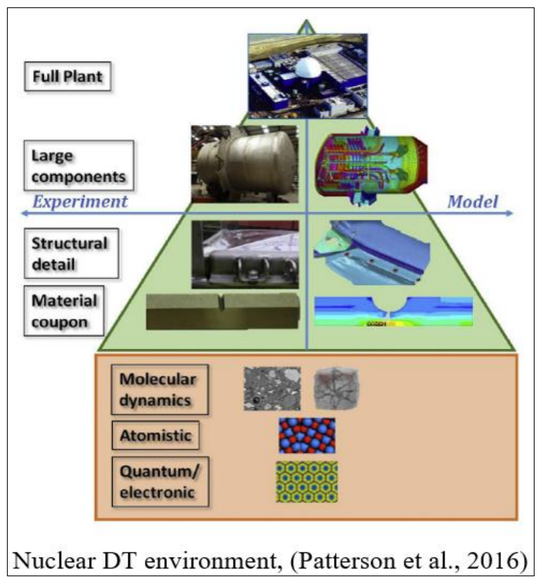
Digital geometry to support a gas turbine DT, (Dawes et al., 2019)



DT for a power-plant unit, adapted from (Xu et al., 2019)

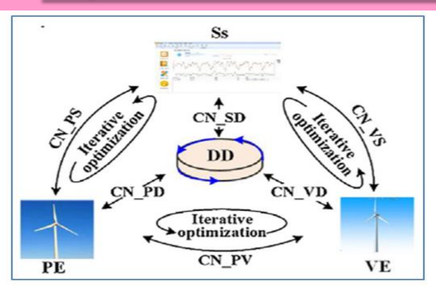


DT to simulate how a product (water pump) will perform in the real world, adapted from (Ferguson et al., 2017)

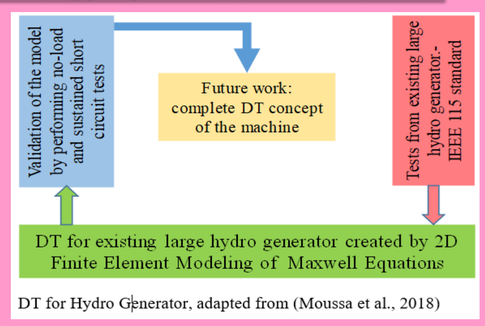


Nuclear DT environment, (Patterson et al., 2016)

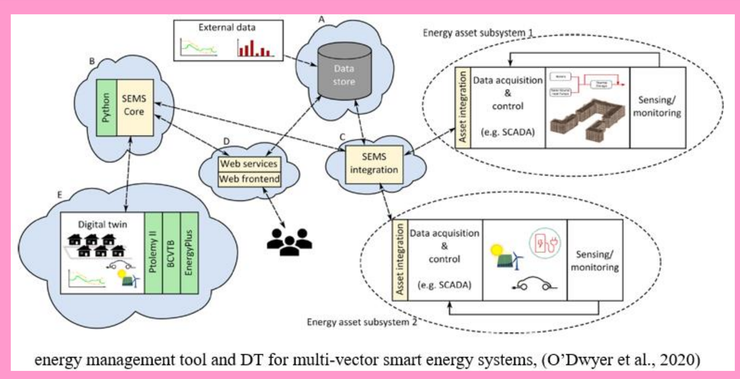
Digital twin for renewable energy systems



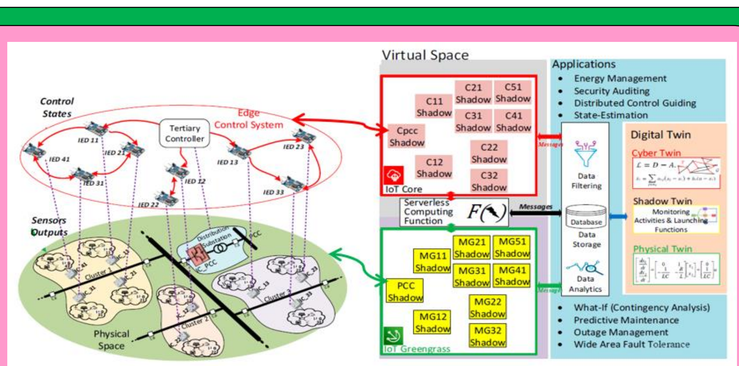
DT for Wind turbine case study, (Kahlen et al., 2016)



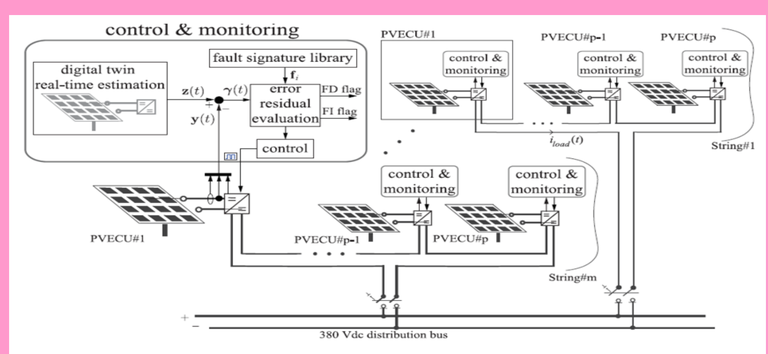
DT for Hydro Generator, adapted from (Moussa et al., 2018)



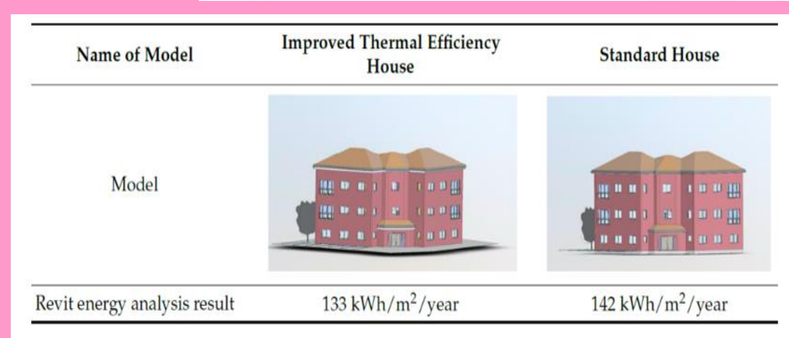
energy management tool and DT for multi-vector smart energy systems, (O'Dwyer et al., 2020)



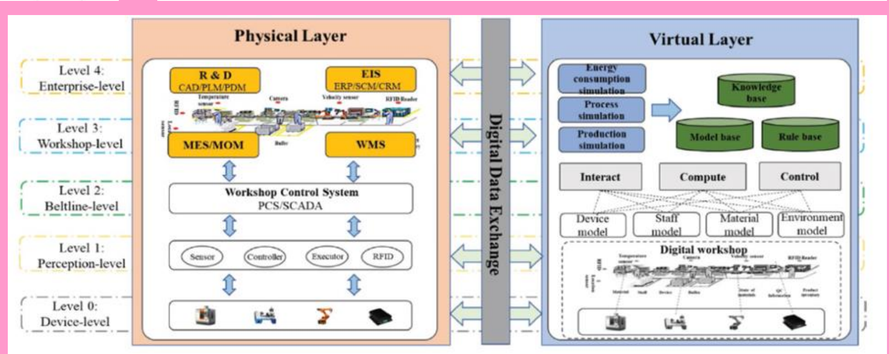
IoT-based DT for ECPSs, (Saad et al., 2020a)



DT for fault diagnosis in distributed PV systems, (Jain et al., 2020)

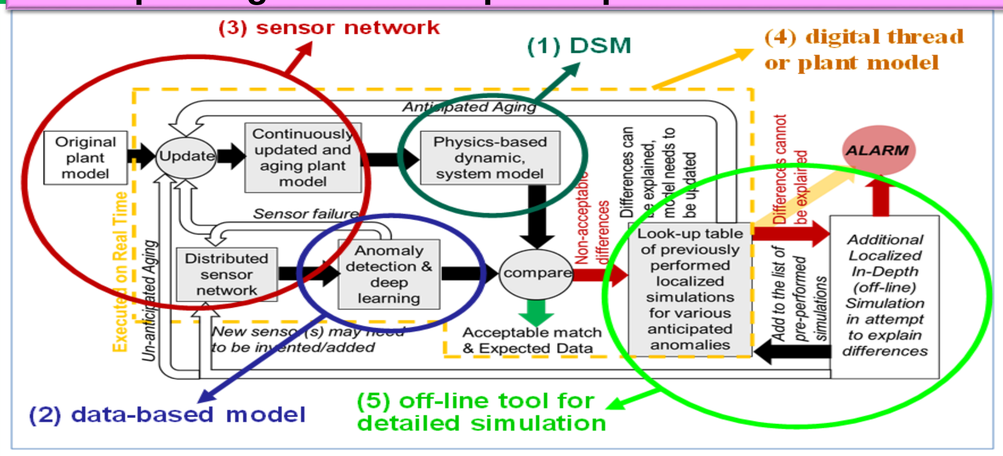


DT using BIM Evaluation of Net Zero Energy Existing Buildings, (Kaewunruen et al., 2018)

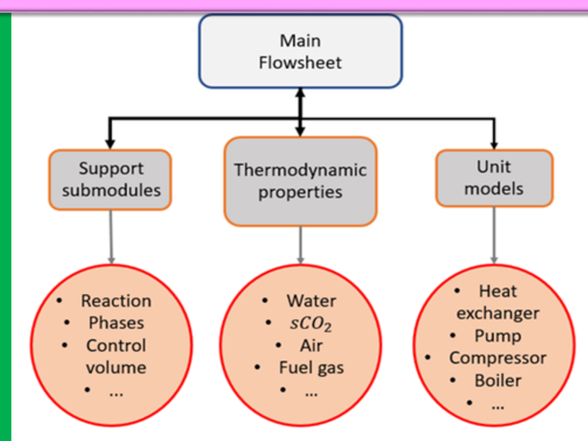


DT for smart manufacturing robotic cellular, (Vatankhah Barenji et al., 2020)

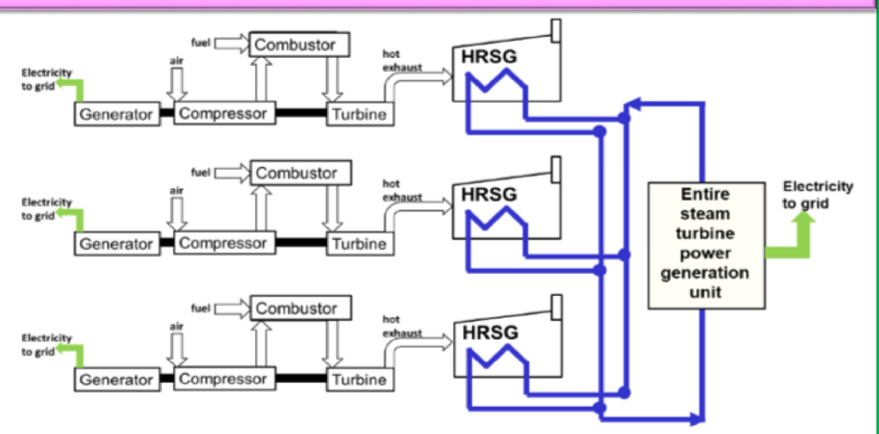
Developed Digital Twin for power plants



The overall flowchart of the proposed power plant DT architecture.



IDAES flowsheet – example.



Power plant schematic, (Goyal et al., 2019).

Conclusions

- The present study also suggests the future directions for DT architecture development for power plants and similar complex systems. The DT development needs real data and physical description of the overall system with focus on each part of the system individually and on the overall connections. Algorithms that are capable of predicting the dynamic behavior of the system with data-driven methods still need more advanced development. Data-driven approach alone is not sufficient and a physics based (low order) model DSM must be operated in tandem with the latest system parameters, to enhance and interpret the results from the data driven process. Discrepancy between DSM and ADL, will require in-depth localized off-line simulation (LDS). All five components of the proposed DT architecture, DSM, DSN, ADL, LDS and System Genome, should be integrated to achieve a robust DT.
- Lastly, it was observed that research related to the importance of integration of energy systems cyber security with DTs has not been reported in open literature (only couple studies listed in Table 2), which makes this subject a priority for future research.

Acknowledgement

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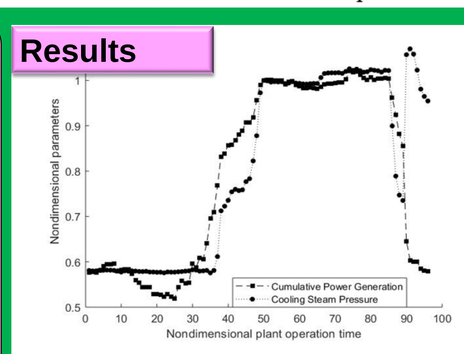
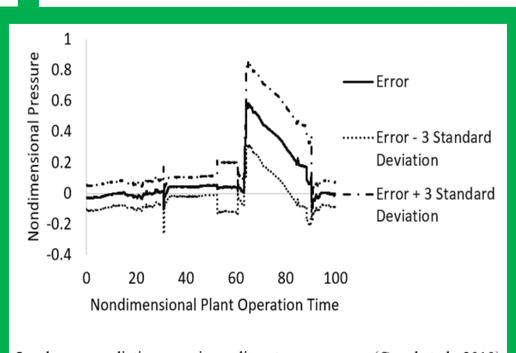
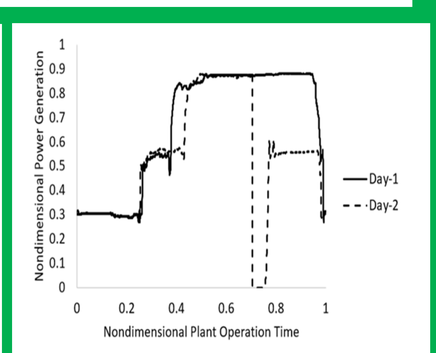
Results



Unexpected change in the pressure of the cooling steam, (Goyal et al., 2019).



In advance prediction error in cooling steam pressure, (Goyal et al., 2019).



The power generation failure – real-time measurement, (Goyal et al., 2019).

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