A.2. Energy futures

Engineering Solutions for a Clean Energy Future. Contributions to this stream are invited to explore applications of MBSE and digital engineering to structure, de-risk and streamline energy transformation to a resilient, net zero emissions future, considering the need for wide accessibility of capabilities and insights across society and enhanced stakeholder trust and experience.

Lead: Stephen Craig, Sam Mancarella
Domains: Energy & Nuclear Technologies, Sustainability and the Environment, Transport & Cities

Submissions Summary:

1. An Austere Digital Engineering Approach for Energy Decarbonisation (Full Paper)
2. Disruption in Energy (Panels and Workshops)
3. Taming the Complexity in Australia (Paperless Presentations)
4. Understanding the Asset-Level Resilience & National-level Sustainability of the American Multi-Modal Energy System (Paperless Presentations)
5. Developing a Hetero-functional Graph State Estimator of the American Multi-Modal Energy System (Paperless Presentations)
6. Transitioning to Net-Zero - a State-of-the-System Analysis (Paperless Presentations)
7. Applying Model-Based Systems Engineering to transforming power systems (Paperless Presentations)
8. K.I.S my MBSE (Keep it Simple) (Paperless Presentations)
9. A Systems Approach to Procurement of a large Power Transmission Program in Europe (Paperless Presentations)
10. Accelerate Electrification of Mine Operations through a Systems Approach (Paperless Presentations)

21004 An Austere Digital Engineering Approach for Energy Decarbonisation

Mark H Unewisse 1, Stephen C Cook 1, John Wharington 1, Duane Jusaitis 1, Ashok Samalam 1, Shoal Group Pty Ltd, Adelaide, SOUT AUSTRALIA, Australia

Keywords: Energy Decarbonisation,Modelling,Digital Engineering

Type: Full Paper
Stream submitted: A.2. Energy futures

Digital engineering (DE) is an active area of research in systems engineering. This paper explores the application of digital engineering to complex, large-scale energy decarbonisation projects. Energy decarbonisation projects are highly diverse in nature, spanning multiple industries, such as: energy generation, transportation, and mining. A DE approach that combines systems engineering design and analysis, supported by physics-based modelling, can be used to effectively understand, design, and deliver these often complex projects. However, such an approach can quickly become highly resource intensive. The paper addresses this issue though a flexible yet cost effective approach that utilises a modular combination of model-based systems engineering, physics-based modelling, and operations analysis techniques to analyse a range of energy decarbonisation projects. Furthermore, many energy decarbonisation projects are enterprise activities with a range of critical externally controlled elements or effectively function as a strategic alliance with significant independence in the development of the component systems. The paper describes how lessons from defence mission engineering can be used to address these system-of-systems aspects and shape the modular DE approach. Finally, the paper outlines some examples from the mining industry of applying this modular digital engineering approach.

20708 Disruption in Energy

Jawahar Bhalla 1, Shoal Group / University of Adelaide, Harrington Park, NSW, Australia

Keywords: Energy Disruption

Type: Panels and Workshops
Stream submitted: A.2. Energy futures

There is growing discussion on energy sources, with political and technological motivation for cleaner, renewable energy catalysing a transition from traditional sources such as coal and gas to solar and wind, as well as options such as hydrogen, nuclear sources coming of age. Differing passionate perspective are leading to divergent initiatives that some say are being rushed through as symptomatic quick fixes, causing disruption in the energy market in the short term at best, with the potential for societal negative outcomes in the longer term. This panel brings together passionate professionals sharing personal and varying perspectives on this contemporary societal disruptor, fostering thought, discussion and insights to towards improving our collective understanding on the opportunities and challenges related to energy and in ideally fostering working a holistic way forward.

21060 Taming the Complexity in Australia

Amro Farid 1, CSIRO Smart Energy Mission, Lyme, NEW HAMPSHIRE, United States

Keywords: energy systems,infrastructure systems,hydrogen systems,water systems,systems-of-systems

Type: Paperless Presentations
Stream submitted: A.0. Advances in Domains (multiple streams)

Overview: In this presentation, we present a reference architecture for Australia's multi-energy, water, and hydrogen systems. For the first time, we begin to understand the inherent interdependencies between these systems using model-baseed systems engineering. Context:Australia has one of the greatest solar and wind energy resources in the world. And yet, it is one of the largest exporters of carbon-intensive energy sources. In the meantime, its arid, sub-tropical climate leaves it water scarce and vulnerable to extreme weather events. Purpose:As Australia proceeds with its own sustainable energy transformation, it must reconcile these realities so that energy services are sustainable, affordable, resilient, and equitable. The interdependencies between is multi-energy, water, and hydrogen systems can create opportunitistic synergies and inevitable trade-offs. Approach:This presentation exposits a reference architecture as a means of managing the complexity of Australias Nexus Infrastructure of Energy, Water and Hydrogen (ANIEWH). It argues that Australia must adopt an integrated approach to infrastructure systems engineering that explicitly tackles the coupling of energy, water, and hydrogen. It further argues that a model-based systems engineering reference architecture provides the disciplinary means by which to tackle this inherent complexity. Insights: The Hydrogen-Energy-Water Reference Architecture (HEWRA) is then presented in terms of system boundary, form, and function for the coal, oil, natural gas, electric power, hydrogen, potable water, and wastewater management sectors. The presentation concludes with thoughts on how this work can be further advanced within future initiatives.

21061 Understanding the Asset-Level Resilience & National-level Sustainability of the American Multi-Modal Energy System

Amro Farid 1, CSIRO Smart Energy Mission, Lyme, NEW HAMPSHIRE, United States

Keywords: energy systems,infrastructure systems,water systems,hydrogen systems,systems-of-systems

Type: Paperless Presentations
Stream submitted: A.0. Advances in Domains (multiple streams)

Overview: This presentation uses hetero-functional graph theory to understand the asset-level resilience and national level sustainability of the American Multi-Modal Energy System (AMES) Context:The challenge of global climate change necessitates a fundamental and holistic re-design of the AMES. Traditionally, the electric grid, natural gas, oil, and coal systems have been studied individually. More recent efforts have tried to study pairs of these systems but for a number of theoretical and practical reasons such efforts have fallen short of combining these four systems into an integrated model. Purpose:The "American Multi-Modal Energy System Synthetic and Simulated Data (AMES-3D)" project funded by the (American) National Science Foundation seeks to fill this gap and produce an open-source, physically-informed, machine-learning, structural and behavioral model of the AMES for potential use and expansion by the broader scientific community.This presentation seeks to introduce the audience to the AMES' data, model and development in several steps. Approach: Hetero-functional graph theory is briefly introduced as the scientific basis for producing structural and behavioral models where an arbitrary number of infrastructure networks of arbitrary topology are connected arbitrarily. Insights: We briefly compare the network statistics and resilience measures of the (traditional) formal and hetero-functional graphs of the American electric power system. Such a comparison motivates the use of hetero-functional graphs in systems with multiple energy carriers and facilities with fundamentally heterogeneous function. In particular, we show how such systems require 3D degree distributions that differentiate the processes and energy carriers in a hetero-functional graph. Finally, we demonstrate how such 3D degree distributions in the states of New York, California, Texas, and the entire United States differ as a result of their fundamentally different geographies and policies. The presentation concludes with several directions for future work using the AMES model and the hetero-functional graph theory toolbox.

21062 Developing a Hetero-functional Graph State Estimator of the American Multi-Modal Energy System

Amro Farid 1, CSIRO Smart Energy Mission, Lyme, NEW HAMPSHIRE, United States

Keywords: energy systems,infrastructure systems,hydrogen systems,water systems,systems-of-systems

Type: Paperless Presentations
Stream submitted: A.0. Advances in Domains (multiple streams)

Overview: This presentation develops a hetero-functional graph state estimator of the American Multi-Modal Energy System Context:As one of the most pressing challenges of the 21st century, global climate change demands a host of changes across at least four critical energy infrastructures: the electric grid, the natural gas system, the oil system, and the coal system. In the context of the United States, this paper refers to this system-of-systems as ``The American Multi-Modal Energy System (AMES)". Purpose:These combined changes necessitate an understanding of the AMES interdependencies both structurally and behaviorally to develop and enact effective policies. Approach:This work focuses on behavioral analysis methods to provide examples of how to analyze system behavior and the crucial flows of energy through the system. Building upon past works, the AMES is modeled and its behavior is analyzed using Hetero-functional Graph Theory (HFGT). Specifically, the work presents a state estimation model of the AMES. Insights:This work brings the state estimation analysis out of the single-operand electric grid environment and into the heterogeneous environment that is the AMES. Employing a data-driven and model-based systems engineering approach in combination with HFGT a Hetero-functional Graph State Estimation optimization program was developed to optimize the flows of mass and energy through the AMES. This provides the first example of using a state estimator with HFGT to model the flows of mass and energy across multiple energy systems contained within the AMES.

21221 Transitioning to Net-Zero - a State-of-the-System Analysis

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Keywords: Net-Zero,Electrification,Renewable Energy,Energy Transition,Battery Storage

Type: Paperless Presentations
Stream submitted: A.1. Electrification

The transition to net-zero by 2050 is a worthy (and critical) goal. It will require electrification of carbon-emitting processes (cooking, heating, transport) and clean sources of electricity generation. The good news is that industry is leading the way, and we may be closer to achieving net-zero than we think. This presentation is a 'State of the System' analysis of where we (Australia and the World) are at with respect to this transformation. It will cover: electrification of transportation assets (EVs, rail, aircraft, ships); clean electricity generation (distributed solar, large scale solar, wind and hydro); and storage (pumped hydro, grid-scale batteries, home batteries and Vehicle-2-Grid technology).

20872 Applying Model-Based Systems Engineering to transforming power systems

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Keywords: Power System Architecture,Model-Based Systems Engineering,Complexity,Decarbonisation,Multi-stakeholder Participation

Type: Paperless Presentations
Stream submitted: A.2. Energy futures

Systems Engineering disciplines and tooling have been successfully adopted by many other sectors that work with highly complex systems. By comparison, their application in the electric power sector has been negligible. Here we explore how MBSE can support the analysis, rationalisation and evolution of the massively complex architecture inherent in Australias largest legacy GW-scale power system as it transforms. GW-scale power systems are some of the largest and most complex systems ever created by humans. Global progress toward deep decarbonisation of legacy grids presents significant challenges as traditional sources of generation are withdrawn and new highly variable, weather-dependent, locationally dispersed, numerically large, and non-merchant resources take their place. Inthis transformational context, the purpose of this work was to explore MBSEs potential to: Provide tooling that enables the decomposition and taming of the massive complexity inherent to transforming legacy GW-scale power systems; Empower more informed, multi-stakeholder participation by making critical content explicit and tractable which would otherwise remain opaque and intractable; and, Increase decision quality, timeliness and traceability to increase the potential for full benefits-realisation and avoiding the propagation of unintended consequences. A key focus of the work was modelling the underlying as-built architecture of Australias National Electricity Market (NEM) power system, potential transitionary and plausible future step change architecture that accommodates the cyber-and physics-based realities of deeply integrating millions of diverse energy resources to become an integral part of a 21st century power system. Given limited precedence in applying MBSE to power systems, an important first step was the model configuration including a taxonomy of logical interface types. MBSE provides a shared systems-based methodology to develop integrated solutions in support of a transition to advanced whole-system coordination that spans bulk power, transmission, distribution, and aggregation of distributed resources to the benefit all.

21169 K.I.S my MBSE (Keep it Simple)

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Keywords: MBSE,Energy System

Type: Paperless Presentations
Stream submitted: A.2. Energy futures

The Energy System is immensely complex. Many actors participate in the Energy System performing a varied taxonomy of roles. Many of these actors are not engineers, let alone systems engineers, but have significant gravitas and influence over the Energy System and, consequentially, our journey to Net Zero. In recent decades, much of the development of the Energy System has been achieved through an incremental approach following established industry methods and practices. The adoption of contemporary systems engineering methods has, perhaps, been slower than in other industrial and innovation areas. Making robust decisions and changes is dependent upon having the best possible knowledge of the subject system. In the case of the Energy System, it is difficult enough to gain consensus on where the boundary of that system lies, let alone gather and present the structure, information and interdependence of the that system in a logical, repeatable and most importantly, usable way. MBSE presents itself as a potential discipline that is capable of achieving these objectives. Initial attempts at using MBSE to develop a model representing the Energy System have, however, proven to be difficult. The number of different diagrams and relationship types that can be utilised in MBSE modelling is off putting to none MBSE users and they quickly lose interest. Users want to be able to see the information, not learn a modelling language. A solution we propose is to hugely simplify the MBSE modelling diagrams, relationships and modelling techniques for the vast majority of users, creating a general model of the Energy System that can be repeatably expanded and be used by all for analysis, research and insight. This general model can then be used as a baseline for more detailed and bespoke modelling using the full power of MBSE on an as needs basis.

21170 A Systems Approach to Procurement of a large Power Transmission Program in Europe

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Keywords: Systems Engineering approach,Procurement of large Power Transmission program in Europe,Collaboration with market parties,Data-centric way of working,Risk-based contract management

Type: Paperless Presentations
Stream submitted: A.2. Energy futures

This presentation explains how TenneT, A transmission system operator for 43 million domestic and business users in Germany and The Netherlands applied a systems approach to stakeholder management, Engineering, Procurement and change management to deliver its largest power transmission program ever. By 2050 the European Union aims to become the first carbon-neutral continent. By 2030, the EU wants to reduce CO2 emissions by 55%. To hit these targets, Germany and The Netherlands need rapid electrification, in industry, mobility and households. The share of electricity in the energy system will grow exponentially, from 20% today to 40-60% in 2050. As one of Europes largest Transmission Service Operators (TSOs), TenneT needs to develop a grid that can support societys climate ambitions: they call this their 2045 Target Grid. Therefore, several offshore wind energy areas have been designated to generate more sustainable energy. These need to be connected to the national grid and thus the 2GW Program was launched. To make the 2GW program successful TenneT decided it needed standardisation, scalability and optimisation; they wanted to ensure each of the 17 projects experiences benefited the next. They also wanted an approach where people within and outside TenneT can work together effectively.Tennet choseaprogressivesystems engineeringapproachto manage these issues.including the implementation of systems engineering, a data-centric way of working , forming partnerships with big contractors, and risk-based contract control to limit their review effort. This new approach for the largest energy transition program of Europe comes with a big organizational change while the projects are already running. Dutch Boosting Group and TenneT will present how they successfully applied and continue to apply Systems Engineering on the 2GW program in collaboration with the contractors, what challenges we have encountered, what the success factors are and what lessons they have learned.

21255 Accelerate Electrification of Mine Operations through a Systems Approach

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Keywords: MBSE,Digital Engineering,Simulation,Transformation,Electrification

Type: Paperless Presentations
Stream submitted: A.2. Energy futures

The International Council on Mining and Metals (ICMM) has committed to achieving net zero emissions by 2050. Diesel-powered mining vehicles contribute 30 to 50% of direct emissions at mine sites, electrifying them will be critical to achieve global decarbonisation goals. Electrifying the mine presents challenges on assessing the impact on mine operations a change in fleet composition will have, as well as how best to operate the future of the mine with these new systems. Systems thinking and digital engineering tools can be used to enable timely, informed decisions to meet emission targets without productivity loss. The proposed solution combines system engineering and physics simulators to allow the contextualisation of changes to operations driven by electrification. Model-Based Systems Engineering (MBSE) will be used to create the Mine System Design, capturing the data and processes of the mine, the configuration of assets and the benchmark metrics and pass/ fail conditions. The Vehicle State Simulation will model detailed energy behaviour of the Haul Trucks (either Diesel or Electric). The Vehicle state simulation will receive variables from the Mine system to model the detailed energy consumption behaviour of trucks and incorporate this constraint into the system model. By leveraging co-simulation what-if scenarios of different fleet configurations and charging infrastructure can be benchmarked within the context of the mine as a system. Creating a realistic decision-making tool to accelerate the electrification process, driving efficient capital and investment planning and meeting emission targets.
