Energy Catalyst

Topic 7 – Architecture

2023/24

Commonwealth Scientific and Industrial Research Organisation

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Contents

1. Introduction

The purpose of the Stage 3 of Global Power System Transformation research focused on Architecture (Topic 7) is identifying appropriate future power system architectures for coordinating new technology capabilities, regulatory approaches, market design, and the distribution/transmission interface in a highly distributed, variable renewable energy-based system.

The research aligns with the Action Research Plan developed in Stage 1, which was informed by a review of over twenty projects and initiatives in the United States, the United Kingdom and Australia. This analysis aimed to identify and recommend an integrated and adaptive combination of 'best practice' methodologies and activities suitable for application in Australia. In Stage 2, global best practice methodologies were 'road tested' in the development of a Reference Architecture aligned with AEMO's 2050 Step Change Scenario. This Reference Architecture included an integrated set of artefacts as outlined in Figure 1 below.

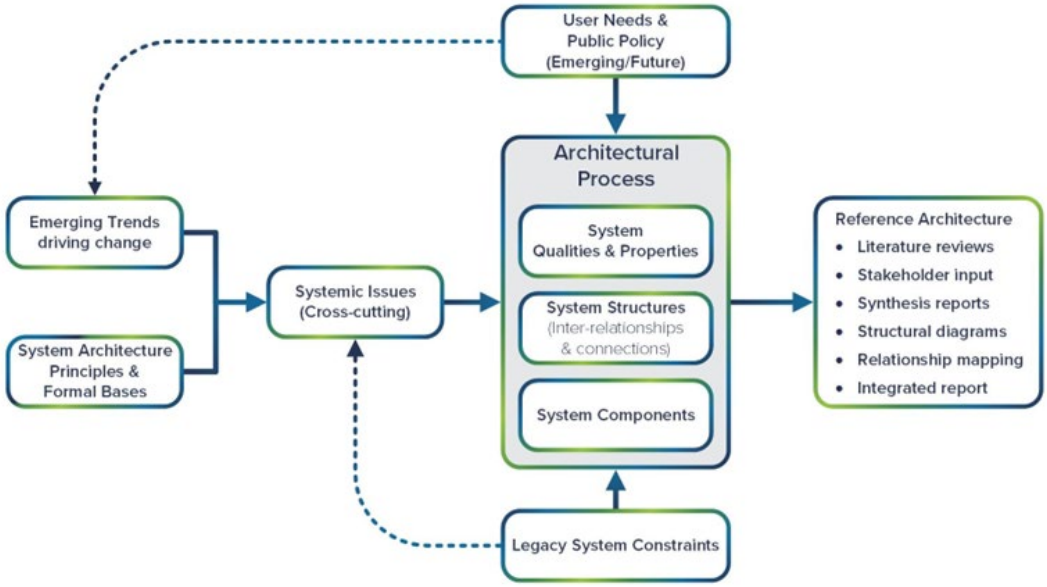

Figure 1 - Reference Architecture Development Process

In Stage 3, Energy Catalyst is expanding the application of architectural tools, with a practical focus on immediate priorities for the NEM, SWIS and DKIS. This will support more strategic and holistic approaches to power system transformation that enable policy ambitions, enhance customer outcomes and are cognisant of physics-based opportunities and constraints.

2. Research completed

A key component of research activities to date has been deep collaboration with AEMO's Future Energy Systems (FES) team on their Functional Requirements for integrating DER from the perspective of the System Operator. AEMO have been undertaking a review of bulk power system responsibilities, together with situations they need to prepare for to operate a high DER/CER system, in order to derive the Functional Requirements needed to continue to manage the system safely. By defining clear Functional Requirements for the operation of the bulk power system, AEMO hopes to contribute to a renewed discussion surrounding the roles and responsibilities of all market and system actors towards the management of a High DER/CER-based power system. In this context, Energy Catalyst has worked closely with the FES team to interrogate AEMO's description of 'system operator' Functional Requirements, assisted by the MBSE tooling being advanced under the PSA Stage 3 project. Specifically, this includes how the "architectural objectives" associated delivering these Functional Requirements are defined; how these Functional Requirements might manifest across the four functional layers set out in the PSA Network of Structures; and, some consideration of staged uplift over time starting from current capability – loosely, from shorter term measures to manage today issues, that can appropriately evolve and scale to meet the step change we expect to see.

The above collaboration with AEMO has been incorporated into the Enhanced Project Scope (Deliverable 1F). This updated scope forms the basis for the following broader update on Topic 7 research activities:

1. PHASE 1 – Project Initiation		
Focus Areas	**Deliverables**	**Status**
1.1. Detailed project workplan and statement of deliverables Informed by initial discussions with CSIRO and AEMO, deliver a detailed Project Plan and statement of deliverables.	1A. Project plan.	Complete
1.2. Workshop workplan and statement of deliverables with CSIRO & AEMO Design and convene a workshop of nominated AEMO and CSIRO staff to ensure maximum alignment between the Stage 3 project and key priorities and practical applications for both entities. Establish a cadence of regular in-person meetings with AEMO to ensure close alignment on key content.	1B. Workshop designed and executed. 1C. Summary of outcomes and ongoing meeting cadence.	Complete
1.3. Workshop workplan and statement of deliverables with International Expert Panel (IEP) Design and convene a workshop of IEP members to: a) review and provide feedback back on the proposed project design; and, b) identify international project collaboration opportunities.	1D. Workshop designed and executed. 1E. Summary of outcomes.	Complete
1.4. Incorporate enhancements in detailed project workplan and statement of deliverables Informed by workshops with CSIRO, AEMO and the IEP, incorporate any enhancements in project plan and supporting Gantt chart.	1F. Enhanced Project Plan	Complete

2. PHASE 2 – Project Inputs

Focus Areas	Methodology	Status	Insights & Results
2.1. Analysis of Model Based Systems Engineering (MBSE) software applications Research and assess industry best practice in adoption of formalised graphical notation languages and development environments for architectural representations of the different systems. Select and configure platform for application to G-PST Stage 3 project that is: • Aligned with methodologies employed in the CSIRO Smart Energy Mission; and, • Most fit-for-purpose for transitioning G-PST Stage 2 'As built' and 'Step Change' architectures to MBSE format.	• Desktop Review. • MBSE expert interviews. • Trial of MBSE software.	Complete	• Selected vendor: Dassault Systemes CATIA Magic Cyber Systems Engineer.
2.2. User-friendly PSA information for senior stakeholders To support the engagement of diverse senior stakeholders on the potential benefits of advancing a Detailed Architecture project, produce user-friendly PSA information designed to support collaborative discussions leading to subsequent co-design workshops.	• Research key stakeholder questions and barriers • Develop narrative and third-party validations	Final Draft	• A key output of this expanded work is the Future Grid Accelerator website, animation and open-source database: https://futuregridaccelerator.com/ • An additional animation has been developed to outline why architectural tools are critical to provisioning the power system for a 'Step Change' future.
2.3. Research architectural inputs for Australia's more whole-system oriented demonstration projects Identify primary sources and key contacts needed to develop architectural mappings of Australia's more whole-system oriented demonstration projects, including: • AEMO / AusNet - Project EDGE • Western Power - Project Symphony • Ausgrid - Project Edith	• Desktop Review • Demonstration project team interviews	Complete	• Key source material has been catalogued and interrogated for relevance. • Briefing to key AEMO demonstration project stakeholders provided. Follow-up discussions in-train.
2.4. Research current status of the three target issues agreed with AEMO and collaboratively engage on their baseline Functional Requirements draft report Research and document the current status in market/regulatory and industry proceedings for the following target issues and provide review and feedback on AEMO's relevant Functional Requirements draft report. • **Emergency DPV Curtailment** – focused on the management of Minimum Operational Demand (MOD) and including considerations regarding the mass-scalability of Dynamic Operating Envelopes (DOE); • **Operational Forecasting of DER/CER -** including initial consideration of entity roles and responsibilities; and, • **DER/CER Scheduling** – including initial consideration of entity roles and responsibilities, DSO models, communications routings and structural cyber-security vulnerabilities.	• Desktop Review • Demonstration project team interviews • In-person working sessions with AEMO Future Power System team to align project activities	Ongoing	• Detailed discussions with AEMO's Future Energy Systems team conducted. • Preliminary instantiation of architectural choices for Functional Requirements in MBSE environment undertaken.

3. Outstanding activities

3. PHASE 3A – Architectural Mapping and Analysis of Targeted Issues			
Focus Areas	**Methodology**	**Status**	**Insights & Results**
3.1. Collaboratively engage with AEMO to jointly develop an initial model for DER/CER categorisation and DSO/DNSP functional requirements Jointly develop an initial set of DSO/DNSP functional requirements cognisant of short term / immediate needs; scalable emerging / transitioning steps; and, long term approaches capable of supporting a future similar to AEMO's Step Change scenario To support this, jointly develop a taxonomy of DER/CER participation and system services to provide a 'common language'	• Mutual NDA established • Desktop Review • Weekly or bi-weekly working sessions with AEMO Future Power System team	Ongoing	• Detailed discussions with AEMO's Future Energy Systems team ongoing.
3.2. MBSE-based mapping of two key G-PST Stage 2 architectures and Australia's more whole-system oriented demonstration projects Develop MBSE-based architectural mapping of G-PST Stage 2 NEM architectures and Australia's more whole-system oriented demonstration projects including G-PST Stage 2 'As built' architecture; G-PST Stage 2 'Step Change' architecture; AEMO / AusNet - Project EDGE; Western Power - Project Symphony; and, Ausgrid - Project Edith.	• MBSE-based architectural mapping of G-PST Stage 2 and nominated demonstration project architectures. • Stakeholder review and feedback on findings. • Stakeholder feedback incorporated into final content.	Ongoing	• 'As-built' and 'Step Change' reference architecture modelling well advanced • Preliminary instantiation of DER demonstration projects undertaken.
3.3. Analyse and report learnings relevant to targeted NEM issues Informed by the architectural mapping of various proposed future models (Item 3.2), and inputs from AEMO's DER/CER work program, conduct comparative analysis of the possible pathways for Emergency DPV Curtailment, Minimum Operational Demand (MOD); Operational Forecasting of DER/CER; DER/CER Scheduling, and Distribution System Operator (DSO) models and their related Roles & Responsibilities.	• Comparative analysis of alternative architectural models to identify strengths and weaknesses relevant to three targeted NEM issues. • Regular in-person working sessions with AEMO Future Power System team to leverage shared insights & external stakeholder review and feedback on analysis.	Outstanding	
Phase 3B Exploration and Co-design of Detailed Architecture Process			
3.4. Multi-stakeholder Engagement In parallel with the above practical demonstration of value, work collaboratively with CSIRO, AEMO and a diverse range of external stakeholders to communicate and workshop the value of both the work-to-date and of potentially progressing to a Detailed Architecture phase.	• Stakeholder mapping and prioritisation, outreach and interviews. • Briefings of industry bodies.	Outstanding	
3.5. Multi-stakeholder Co-design of Detailed Architecture process Informed by the above process of engagement, design and implement a process of stakeholder co-design of a Detailed Architecture process that would enjoy a high level of multi-stakeholder participation and the in-principal support of market/regulatory bodies.	• Development of Detailed Architecture prototypes for discussion. • Detailed design of stakeholder co-design workshops. • Regular in-person working sessions with AEMO Future Power System team to ensure alignment.	Outstanding	

4. Progress against the Roadmap

Topic 7 research remains well aligned with the broader objectives of the G-PST Research Roadmap. The research team has taken opportunities to engage with the work of other topics, notably Topic 8 – DERs and Topic 4 – Planning.

5. Research relevance

Global electricity grids are experiencing levels of operational volatility not anticipated by their original architects as variable renewable generation is deployed at massive scale. This is further compounded as the withdrawal of conventional 'dispatchable' generation accelerates. This is because synchronous generation has provided essential system services needed by the grid and the flexibility to balance supply and demand every second of the year.

For our deeply decarbonised Future Grids to be secure, cost efficient and customer-centric, these complex physics-based systems increasingly require bulk power, transmission and distribution systems – and the rapidly expanding fleet of distributed resources – to be made capable of functioning far more dynamically and holistically end-to-end as an integrated, self-balancing system.

Designed as traditional linear supply chains, however, our legacy power systems have often been deeply 'siloed'. Many professionals working, for example, in the distribution sector have required only limited or no interaction with the bulk power system, and vice versa. By contrast, these ultra complex systems are now experiencing a profound transformation, ultimately requiring them to become far more dynamically interdependent. Occurring at unprecedented scale and pace, this requires new ways of thinking and working together that are far more holistic, inclusive and integrative.

Establishing a sound architectural framework, cognisant of the required performance envelop of the system through to 2050 is of critical and foundational relevance Australia's transforming and future electric power systems.

6. Recommendations

In Stage 3 of the G-PST initiative, the architecture work has focused on expanding formal methodologies for making architectural trade-off decisions. Notably, the introduction of MBSE – a toolset extensively adopted by other sectors to manage complex systems but largely absent from the power sector, has provided a significant capability uplift. Having established and matured the range of formal methodologies for making architectural choices, this body of work is now well positioned to undertake a Detailed Architecture process in 2024/2025. This would require a high level of multi-stakeholder participation and the in-principal support of government/market/regulatory bodies and processes, and ideally feed into parallel government sanctioned programs of work.