A Use Case Structure for Technology Integration

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***Abstract*— In recent years, integrating innovative technologies into the work domain have reduced workload, simplified the work process, saved business costs, and generated additional revenue. Use case analysis is widely applied to identify functionalities and communicate the applicational details for technology implementations. In this study, we propose a way to frame a use case for effectively communicating across the multidisciplinary team in the design and continuous improvement phases. The use case highlights the heterogeneous and concise characteristics to reduce biases. An electric grid transmission system's dynamic line rating use case example illustrates the structure.**

Keywords—use case, technology integration, communication, electric grid, dynamic line rating

I. Introduction

Over the last few decades, innovative technologies have continuously grown around the world. The annual patent application and grants have increased significantly, according to the U.S. Patent and Trademark Office [1]. Advanced technologies are intended to make our life easier and more convenient but often add more connectivity and complexity for users. The amount of available system information increases dramatically in various work domains. For instance, in aviation, a modern A-320 has around 190 computers that interact without the pilots' awareness [2]. In medical, the electronic health record system could generate a large number of alerts with low positive predictive values, leading to alert fatigue and alerts being ignored by practitioners [3]. In energy, the smart grid that enables incorporating uncontrollable green energy and shifting to distributed generation and resources has also increased the system complexity and the amount of available information [4, 5].

Not all the integrated technologies' available information is useful and meaningful for people who interact with the system. Too much information and nuisances can result in information overload [6]. Any information displayed on a screen competes for attention. On the other hand, hidden technologies' functionalities and design can reduce the situation awareness and result in unintended consequences. The Boeing 737 Max 8 (The Boeing Company, USA) is a recent well-known example with functionalities that can lead to a severe unintended tragedy [7]. The plane tends to raise its nose when the pilot applies power to the engine, so the software, named Maneuvering Characteristics Augmentation System, has been applied to lower the nose when it detects a high angle of attack. Pilots who transitioned to this airplane were not informed about the aerodynamic problem and software. They could not trace and deal with the failure when situations occurred, which led to two fatal crashes in 2019. That is to say, system designers and developers need to identify relevant information for different users when integrating technology.

Creating use cases is a common way to identify functionalities and relevant information in the business, software, and system engineering domain. What is a use case? A use case suggests how the piece of technology might be used. It describes the possible sequences of interactions between the system under discussion and its external actors related to a particular goal [8]. There are various ways to write a use case. It is sometimes represented with a sentence text style or a diagram such as Unified Model Language [8-10]. It may include a description of actors or stakeholders (e.g., the user) who can make decisions, the goals in context, pre-condition, success end condition, failure protection, etc. A use case can provide high-level rough functionality proposals and low-level details of how the technology is implemented depending on the use case's functional purposes [10, 11]. An effective use case can provide requirements for business process redesign, encourage the elicitations of requirements to users and stakeholders, specify test cases, and document the system internals and design behaviors.

When discussing a use case with the stakeholders and design team, it is often referred to as a specific, not multiple, designed option. From convincing people and demonstrating the values aspect, the common use case is often sufficient and effective because the description of how it could use emphasize the added values of technologies. From the risk and resilience standpoint, integrating a technology also increases the complexity and adds more potential failure modes. Scenario planning is sometimes associated with biases [12, 13]. It is necessary to understand how the technology works in generalized contexts, not just for favorable conditions, to ensure the discussion can stay at a relatively neutral position and eliminate some biases [14].

A specific description of a use case sometimes constrains system interaction considerations and what might be the potential concerns when defining how actors may interact with the technology. The generalizability of a use case can become a concern, especially when actors do not work and use the

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proposed technology as intended [15]. Traditionally, a sentence-style use case can contain many details that may or may not matter under unique contexts. Some characteristics are generalizable, whereas others are not. It can be time-consuming to understand the similarities and differences across different use cases, creating a burden for readers to extract generalizable abstract information and figure out the possible combinations of design options and scenarios.

This paper proposes a way to structure a use case for effectively communicating a technology integration to stakeholders and the design team in the design and continuous improvement phase. It provides some guided words and lays out some important information that needs to be resolved when implementing technology, especially for understanding the available human-system interaction design options and finding ways to mitigate the inherent unfavorable characteristics of the technology.

II. Proposed Use Case Structure

The proposed structure is to ensure the use case can be communicated consistently across the stakeholders and the team. It does not replace other use case methodology for project management. As stated before, it is mainly used to ensure the generalizability of how the technology could be used, understand the proposed technology's interaction with humans and other systems, and systematically summarize or brainstorm the design options to eliminate repeated and redundant discussions. As a result, it is:

- Heterogeneous—referring to facilitating the diversity of the use case contents. One way to achieve that is to group similar contents and separate diverse information.
- Concise—Communicating with a concise and information-rich use case document is a way to save time spent writing, reading, and communicating. Like designing a user interface, a clear and attention-driven structure can facilitate and encourage readers to gather the content in a short amount of time.

A. Overview

The use case structure contains six sessions from these aspects:

- Description. It describes the general characteristics of how the technology is expected to be used.
- Primary objectives & purposes. It describes the technology's goals and values added to the system.
- Where & when would it be useful? Any technology has its applied contexts. This session describes the environment, system, or human contexts that can make the technology useful.
- Prerequisites & assumptions. It shows the prerequisites and assumptions that designers and developers made. When those assumptions are violated or challenged, the technology may fail to serve its purpose as expected.
- Human Roles. It indicates relevant staffs' general responsibilities. Humans often serve certain functions in a complex work domain. When designing a system, it is essential to understand its potential direct and indirect impacts on how people achieve the goals and perform the work. Hidden and unknown effects can become hidden hazards.
- How would it be implemented? For any technology integration, the way it would be implemented can have a significant impact on the performance, added value, risks, and resilience, so this session is a place to summarize some front-end and back-end design options, concerns, and mitigation strategies to reduce the negative impacts.

B. Additional Proposed Use Case Features

Some additional features have been included in the use case to guide the description. Based on the definition of a use case, these guided words may not be critical, but these allow us to lay out the interrelations and descriptions concisely.

In this structure, we added the "Or/And," "Or," and "And" statements at the end of some sentences and descriptions in order to clarify the interrelations between several subpoints. For instance, when describing the "where & when would it be useful," "Or" indicates satisfying either of the conditions can make this technology useful, whereas "And" suggests it would only become useful when the substatements and conditions are met. In the "how would it be implemented" session, "Or/And" indicates the combinations of the design options that can be added at the same time, whereas "Or" suggests designers need to select one. It allows practitioners and researchers to consider factors that might affect the overall system performance and simplify the process of conducting experimental design to find optimal solutions.

The "how would it be implemented" session has also been decomposed into three subsessions: human-system interaction, proposed technology, and interrelationships between the proposed technology and current system(s). This structure ensures the aspects are covered in the use case description. The human-system interaction describes the concerns and available design options for people to interact with the system when implementing the technology. The proposed technology part emphasized understanding the assumptions that each technology made so the assumptions can be well-communicated to users and front-end designers, especially when the development process requires people to understand and detect the technology's failures. The interrelations between the proposed technology and current systems summarize what needs to be considered during the technology integration process. The technology's reliability and errors can affect users' operations and the design of human-system interactions.

III. A Use Case Example

A use case related to the ambient states-based dynamic line rating (DLR) technology for a transmission system is an example of how to use this structure. Transmission capacity has often been limited by the conductor's thermal capacity with the static line rating (SLR), which is based on constant weather conditions over a period of time (e.g., winter). DLR estimates line ampacity (maximum current carrying capacity of a transmission line) in real time with instant monitored weather conditions (e.g., wind, solar radiation) [16].

We conducted the following example based on our understanding of the electric grid operations and attempted to cover as many unique generalizable characteristics as possible. For some technical details that vary case by case, depending on utilities, have not been included. What's more, this use case structure is mainly for the design and continuous improvement across the multidisciplinary team. It can be formatted in other styles (e.g., table) as long as keeping the same content structure and features.

The general description describes the uniqueness between the use cases. For instance, there are several ways of using DLR.

- To replace SLR in real-time operation.
- To prepare plans (e.g., day-ahead) and real-time operation.

This use case focuses on using DLR to replace SLR in real-time operation. The use case's general description is that: "transmission lines are rated dynamically with real-time environmental conditions for real-time operations."

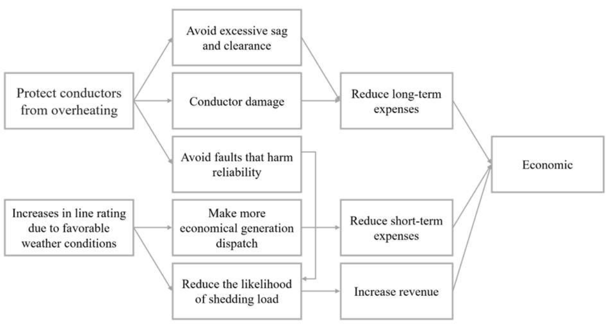

Fig. 1. Indicate the DLR objectives and purposes' relations.

A. Primary Objectives & Purposes

Primary objectives & purposes are the values that this technology can add to the system. It can be as general as the direct values, like the key performance indicators or the values that can contribute to those. In a complex work domain, most technologies can ultimately contribute to the business's economic and regulatory standpoints (Fig. 1). To indicate the uniqueness, we consider using the technology-related objectives and purposes instead. Here is a description of the DLR use case's primary objective & purpose.

- To take advantage of increases in line rating due to favorable weather conditions to:
  - Reduce the likelihood of shedding load.
  - Have a more economical generation dispatch.
- To protect conductors from overheating to avoid:
  - Excessive sag and clearance.
  - Faults that harm reliability (e.g., potential for cascade failure).
  - Conductor damage.

B. Where & When Would It Be Useful

Each technology has its own applied environmental, system, and human contexts. For example, simulation and computational analysis tools are often used to compensate for the cognitive and mental capability to conduct the analysis. Assistive devices are designed for a specific user group (e.g., age). For DLR, the contexts that determine the usefulness are related to the environment and system setups.

- Transmission lines are sometimes operating above their real-time thermally limited capacity but below their SLR, which results in overheated conductors that can sag into trees and nearby obstacles and cause fire, power outages, or electrical hazards to anyone nearby.
  - Environmental conditions (Or): Common extreme high temperature, low wind speed, and high solar flux.
- Transmission lines are often congested with limited or no way to redirect power flows, and the real-time environmental conditions allow operators to take advantages of increases in line rating. (And)
  - System setups: Long-term planning shows the demand will continue to cause more transmission congestion.
  - Environmental conditions (Or): High wind speed; low air temperature; low solar flux.

C. Prerequisites & Assumptions

When integrating technology into a system, the prerequisites and assumptions are the set of requirements and additional functionalities that need to be achieved to ensure the technology can work as expected. These prerequisites might be considered as part of "how would it be implemented." In this paper, we assign a separate session for these because the existing infrastructure and systems determine how easily the technology can be implemented and the additional resources needed. The design and implementation team needs to discuss and pay attention to this before investing too much time. The prerequisite & assumptions in the DLR use case examples are based on our interpretations of how the system work. Here is the description:

- Weather stations have been installed and weather data would be validated.
- Emergency ratings and load dump rating (LDR) are adjusted dynamically with the same algorithms used in DLR.
- Relay settings have been adjusted according to DLR, emergency ratings, and LDR.
- Other settings (e.g., Remedial Action Scheme) related to SLR have been reviewed and tested.
- The contingency analysis can integrate DLR.
- Displayed DLR would not move too rapidly, or it would overload operators.

D. Human Roles

For a complex work domain, people often serve certain functions within the organizations to generate values. For technology integration, the relations between the technology, system, and humans need to be well defined and understood. In the electric grid transmission system, parts of the transmission operators' primary goals and responsibilities are to keep the transmission system operating within the frequency, voltage, and thermal limits [17]. DLR is related to the thermal limits, so human roles are:

- Operators use DLR to relieve real-time or contingency overload when environmental conditions allow and to prevent transmission lines from overheating.
- Engineers analyze historical power flow and DLR data to plan for investment.

E. How Would It Be Implemented

For the same general functions, there are many ways to implement the technologies, which can result in differences in how the system responds, how people interact with the systems, and the overall performance. New integrations often increase the system complexity that requires people to diagnose when the integrated technology fails to work as expected. This session is to facilitate a better understanding of the technologies to allocate functions further, create detailed designs, etc.

1) Human-system interaction: This subsession describes the possibilities of human-system interaction design. The team can use some design principles (e.g., Nielsen's usability heuristics), human characteristics (e.g., physiology, psychology), and other existing technological capabilities to come up with the options [18-20]. In the use case example, DLRs, which change in real time with higher variation, less consistency, and predictability than SLRs, replace SLRs to represent the line limits in real time operation.

- Consistency: Support understanding how the changes in load and generations affect transmission lines' unit power flows. (Or/And)
  - Always display current power flow and each DLR power flow unit mega volt ampere (MVA) or ampere (A). Operators learn the correlations in training, simulation, and operation.
  - Provide computational estimates of how the changes in load and generations affect DLRs unit power flow when needed.
- Variation: Display DLRs estimates. (Or)
  - Operators operate with the median or average of multiple real-time DLR estimates (e.g., DLRs in the 10 second time range).
  - Operators operate with conservative DLR estimates in the next 15 min or 1 h.
- Predictability: Provide DLR time series forecast. (Or)
  - Operators receive DLR's time series forecast without uncertainty measures after requested.
  - Operators receive DLR's time series forecast with uncertainty measures after requested.
- Identify DLR errors. (Or/And)
  - Display indications when not receiving updated DLRs or when DLRs exceed preset or forecasted daily maximum and minimum limits.
  - Allow operators to easily access DLR historical data.
- Mitigate DLR errors.
  - Allow operators to adjust DLRs to minimum preset limits or use SLRs when needed.

2) Proposed technology: This subsession covers the general functionalities related to the technology, assumptions, possible violations, impacts, and mitigations. Figuring out the assumptions can help developers identify and minimize potential points of failure. There are different ways (e.g., ambient states-based, thermal states-based, mechanical states-based) of computing and estimating DLR [21]. We use the steady-state ambient-based approach as an example [22].

<u>Function: Collect real-time weather conditions</u>

- Approach: Installed weather stations along transmission lines
  - Assumption: Weather station data is accurate
    - Violation: Instruments collecting data, but it has a bias
      - Likelihood: Highly likely
      - Impact: Calculated DLR follows same bias
      - Mitigation: Calibrate instruments before deploying and perform regular maintenance
    - Violation: Instrument not collecting data
      - Likelihood: Very unlikely
      - Impact: DLR calculation at location is unavailable
      - Mitigation: Use nearby DLR to infer rating
    - Violation: Incorrect data
      - Likelihood: Unlikely
      - Impact: Calculated DLR is incorrect
      - Mitigation: Implement algorithm to recognize incorrect data
  - Assumption: Data is being transmitted from weather station to utility
    - Violation: Data does not get transferred
      - Likelihood: Unlikely
      - Impact: Data not available for DLR calculations
      - Mitigation: Use neighboring data when available or defer to SLR when no data available.
- Approach: Use a local weather database to pull conditions
  - Assumptions/Violations: Similar as when using weather stations to collect data

<u>Function: Compute the DLR along the path of the transmission lines</u>

- Approach: Calculate the DLR where weather conditions are known
  - Assumption: The conductor is at steady state where heat loss = heat gain [23]

- Violation: The line is not at the steady state when environmental conditions are changing
  - Likelihood: Highly likely
  - Impact: Does not capture the transient heating of conductor
  - Mitigation: Use minimum previous value over a time range

3) Interrelations between the proposed technology and current system(s): Integarating a technology into a system can result in violations of the assumptions built into the system(s) and operations. It results in some difficulties and challenges for technology integrations because that means it requires users to reanalyze the system, understand the impacted systems, etc. In the use case, we stated a summary of inputs, outputs and the affected systems and settings.

- Proposed technology's inputs (e.g., data, controller) from the current systems
  - Path of transmission lines
  - Conductor of transmission lines: diameter, resistance, emissivity, absorptivity
  - Real-time power flow
  - Contingency analysis power flow
- Proposed technology's outputs (e.g., data, controller) to the current systems
  - Real-time DLR power flow unit estimate
  - Contingency DLR power flow unit estimate
- Affected systems and settings
  - LDR
  - ER
  - Remedial action scheme
  - Relays

A real system integration would include a summary of various assumptions related to technology, techniques, and protocols used in the data transfer in the use case. We haven't included it in this use case because it is often system dependent.

IV. Discussion

How can the use case facilitate exploring the available development options? For the use case human-system interaction as an example, there are 36 (3 × 2 × 2 × 3 × 1) combinations of design options. Each of them indicates a special way for operators to interact with the system. The number of available options increases dramatically when the heterogeneous design characteristics accumulate. Splitting and segmenting facilitate and simplify the information identification and search process instead of embedding the information within a long text description.

What's more, we include the assumptions about how it would be implemented. Assumptions are sometimes related to hazards and risks within a system, and a possibly hazardous situation could occur when the assumption collapses. The system theoretic accident model also indicates the importance of tracking the leading indicators of the assumptions [24]. Use the Boeing 737 Max as an example. One of the falsifiable assumptions in the Maneuvering Characteristics Augmentation System was that the detectable high angle attack was the actual angle attack. When this assumption did not hold, the system failed to act as expected, leading to accidents. Thus, when integrating a system, it is necessary to re-examine the existing assumptions and interactions with the technology.

Smart Grid Architecture Model (SGAM) is a use case methodology that includes some similar aspects for project management. SGAM segmented a use case into several layers (i.e., business, function, information, communication, and component layers) that serve separate functionalities [11]. SGAM also has the assumption tracking and management process built into the methodology. However, the SGAM methodology is mainly for single design applications, and that is to say, it lacks the robustness to track several design options. The proposed use case structure fills the gap.

The case study methodology is somewhat similar but different from how a use case is conducted. A case study emphasizes the in-depth examination of a case for real-world applications and complex domains. Given the characteristics, the case study analysis results may or may not reflect the behaviors of similar entities [25]. The validity, reliability, and generalizability are sometimes questioned because a case writer can select from available data to illustrate anything in favor [26, 27]. Unlike a case study, a use case is developed to explore the potential applications. Researchers sometimes implement case studies to establish use cases. To eliminate some biases associated with case studies and specific scenario creation, we highlight the available options and understand the assumptions within the use case.

The proposed use case structure is likely insufficient for project management and tracking. When the amount of information accumulates, writing the information on a word and text document could become less efficient than managing the information with software, depending on the ease of use. It may need additional features and multiple ways to display the information dependent on other purposes, and this use case structure does not include those aspects. It is something we could consider in future research and development.

V. Conclusion

This paper proposes a use case structure for technology integrations and communications across multidisciplinary teams. Some guided sentences or words have been provided so a concise and generalizable use case can be built accordingly. Unlike a traditional use case that only specifies one way of integration, the designed use case indicates the various ways to implement the technology. The team can understand various combinations of design options effectively. A DLR use case has been applied to indicate how the structure can be used.

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