Greenhouse Gas Emissions Reductions Enabled by Digital Twins

William Randell MCNAIR, D.B.A
MetaPassageways
Lakeland, Florida 33806/ United States

Maruthi DEVARAKONDA, Ph.D.
Independent Consultant
Katy, Texas 77494/United States

ABSTRACT

We will shortly describe the using of a digital twin in the context of a near-real time Decision Support System oriented to the objective of making continuous and incremental decisions related to the carbon footprint of an industrial facility, by means of creating projects related to scheduled maintenance turnaround. This may also be related to decisions regarding parallel capital investment, in which case it would support a justification for the associated inversion.

On this article we will shortly describe de context of problem being addressed, the use case assumptions, the potential database Boolean keywords / search strings that will be used and provides a research summary. An editorial note has been included where shortly describe explicitly what implicitly supports and orient this research.

1. INTRODUCTION AND CONTEXT

In 2017, the World Economic Forum (WEF) forecasts digitalization had the potential to generateas much as $1 trillion in value for oil and gas firms by 2025 (WEF, 2017). Since 1990, the US oiland gas industry has average emissions of 5.467 billion metric tons of Carbon Dioxide (CO2) each year. Total US energy related CO2 emissions dropped to 4.575 billion metric tons in 2020attributed to energy demand cutbacks resulting from the COVID-19 pandemic, however much ofthat 11% reduction was considered an anomaly similar to the 7% CO2 energy related emissions reductions the US experienced the year following the 2008 global financial crisis compared tothe peak emissions recorded in 2007 of 6 billion metric tons (EIA report, 2020). The overalltrend since 2007 has been gradual a decline totaling 14% through 2019. While this trend may bedue to in part to the energy transition (an on-going decarbonization of energy production) already underway, digitization promises to contribute more to this trend through direct and indirectcarbon emission reductions from the energy industry, low carbon energy sources such ashydrogen, geothermal and renewables, combined with focused emissions abatement throughmethane emissions management and carbon capture and storage (CCS). These efforts will play acritical role in further realizing the zero emission targets by 2050. This paper explores the role ofa key digitization technology called digital twins in reducing carbon emissions through designand simulation. The hypothetical use case we use to demonstrate the potential benefits of digital twins is as follows: anoperator of an existing complex facility would like to reduce the facility's carbon footprint and thus createa list of potential modification projects to be handled on a scheduled maintenance turnaround (or as aseparate major capital project) should the return on investment justify the expense.

The research effortwould focus on how would having a fully maintained, near-real time accurate digital twin of the facilityprovides

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decision support for creating a list and conducting the analysis of opportunities.

2. USE CASE ASSUMPTIONS

- On-shore Gas/Oil/Water separation processing plant

- Flaring of gas occurs under the following scenarios:

    - Inadequate demand or storage for gas produced by the plant
    - Processing system disruption on incoming gas/oil/water pipelines
    - H2S scrubbing

- Produced Gas is used for power generation for the facility, tank farm, and the surrounding shore base camp

- Infrastructure Maintenance:

    - Facility Pipes are hydrotested periodically for leaks
    - Valves are tested periodically or when repaired/replaced for planned maintenance or when failure is detected

- Technology Assets:

    - Gas Sensors are connected to a control system
    - Alarm/Trip systems are network connected
    - Instrumentation control system is located in a control room within the facility

- Known potential GHG emission sources:

    - Production Water treatment facilities includes sludge ponds
    - Pig receiver system includes a canal for relieving hydrocarbon sludge extracted from pipeline
    - Sewage treatment system is below ground septic tank field
    - Tanks are roofed and have monitored vapor recovery system installed

Background facts regarding potential chemical or process safety hazards:

- Facility has been built over the past 4 decades, evolving with technology and various documentation media of existing assets (e.g. paper, electronic, USB drive, cloud-based) withinconsistent levels of content accuracy relative to the built environment.

- AFFF Foam fire retardant system installed and tested periodically

- Site uses a chemical additive injection system to help with water/gas/oil separation (e.g. defoaming agent)

- Surplus produced gas is also fed to a nearby community power plant via 6” subterranean pipeline constructed ten years ago

- Diesel fuel is refined and stored within the compound and used as follows:

    - powers transport vehicles,diesel generators (used as back up to gas turbines for critical systems), construction tools
    - nightlymosquito fogging
    - amended to soil as Laterite for controllingroad dust

Literature Review/Academic research will focus on the way carbon capture has become an imperative in the modern O&G sector. Strategy for gathering information will leverage books and peer reviewed journals using ABI InformGlobal and exlibrisgroup.com and Google scholar databases. We will also pull in data and insights from white papers, trade journals, and engineering professional journals as needed forbackground and context.

Potential database Boolean keywords and search strings:

"Carbon capt*";energy trans*; "Carbon reduction"; decarbonization strategy; clean energy; hydrocarbon emission*; "green ener*" & "fossil fuel*"; carbon sequest*; "oil and gas" & "leak detect*"; emission*; greenhouse gas reduc*; gas emi*; "agile" & "operat*"

3. RESEARCH SUMMARY

The analysis will include a detailed roadmap for how current digital technologies (3D, AI, IIOT, etc.)could be used to model, simulate, and design more efficient greenhouse gas (GHG) emission abatement systems. Emphasis will be on ensuring process safety while removing unnecessary GHG emission sources due to previous inefficiency or design assumptions that incremental modernization couldmitigate. Work package planning, and concurrent engineering planning will be governed by a Management of Change process to ensure proposed changes are documented and in-progress changes are tracked so that operational activities are respecting lock-out/tag-out, safe work permitting practices, andhazard detection systems are in place and operational during simultaneous operations and hot work activities. Parameters for what constitutes a viable project will be based on a carbon offset valuation model using industry standards for tracking the value of carbon reductions achievable and ultimatelyachieved. Will show how a properly maintained Digital Twin provides a near-real-time means to trackaccurately the actuals vs. hypotheticals and thus update the simulation parameters and model continuously as more data turns assumptions into actual empirical evidence for iterative improvement over time.

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EDITORIAL NOTE

This extended abstract had three reviewers recommending accepting it and NONE recommended not accepting it.

The reader may have noticed what a non-anonymous reviewer, who recommended accepting this paper, wrote in his review: "The abstract describes what should be a very interesting presentation: the potential to use digital twins (applications that faithfully replicate the behavior of large facilities) as a means of reducing facility emissions. The approach planned for the presentation--walking the audience through a concrete case study--is also novel and, in my opinion, is a very good way of keeping the audience engaged. The main limitation of the abstract itself is that it introduces the topics that will be presented and how they will be presented, but it does not provide any details on the findings and conclusions of the presentation. That limits what the reader can take away from it without attending the presentation."

An anonymous reviewer (in his double-blind review) recommended not just the acceptance of this paper but to consider it among the best. This means that the full version of this extended abstract will (after more reviewing) be published in an open journal, indexed by DOAJ (Directory of Open Access Journal), since 2003.

The anonymous reviewer wrote a very important review, because it made explicit what

is implicit in this extended abstract. He wrote the following:

> The article entitled "Greenhouse Gas Emissions Reductions Enabled by Digital Twins" suggest the innovative idea (potentially a very original one) of a Decisions Support Systems based on a Digital Twin, with the objective of making continuous and incremental decisions related to the carbon footprint of an industrial by means of creating projects related to scheduled maintenance turnaround. This may also be related to a parallel capital investment, in which case it would support a justification for the associated inversion.
>
> This is great in several dimensions:
>
> 1. To my knowledge it may generate an important technological innovation which would generate benefits in different dimensions: support the carbon footprint reduction, support maintenance decisions, justify inversions, etc.
>
> 2. It is definitely an original idea as related to a methodological innovation. In this case the diversity of applications cannot be imagined. Any industry may benefit from applying the same idea, i.e. the same "Digital-Twin-Based-Methodology" for Decision Support Systems with a) similar objectives or b) other objectives, different to "Greenhouse Gas Emissions Reductions."
>
> 3. The above is indication of potential for meta-innovations, i.e. a methodological innovation for innovating.
>
> Consequently, I recommend accepting this article.
>
> 4. I also can inform with certainty that, the work that support this article is among the best I have read lately. Its potential is the largest from what I can imagine regarding the application of the associated methodology. It provides decision support in several dimensions: technical, managerial, financial, etc. and, possibly, not just in the area of Greenhouse Gas Emissions Reductions.
>
> 5. I would like to ask the organizers to congratulate the author(s) of the Research and Development described in this article. It is a very good example of the synergy that may be produced between KNOWLEDGE AND EXPERIENCE. I recommend this article as among the best. It may even be THE BEST in the area of Research and Development and as associated to its potential for technological innovations and, even, meta-innovations.

An internal meta-reviewing triggered another internal reviewing of this extended abstract and as a consequence the Conference General Chair decided to invite the authors of this paper for a plenary keynote address at the conference if 1) they accept to make a presentation oriented to a multi-disciplinary audience and 2) stress what the anonymous reviewer made VERY explicit about what was evidently implicit in the Research and Development briefly described in the extended abstract.

This extended abstract show several important issues that should be known to the multi-disciplinary audience. Some of them are the following:

1. The synergy usually achieved in an adequate (cybernetic)relationship between Academics and Industry

2. The importance and, frequently the necessity, of this relationship in order to solve real life problems in the context of real life restriction such as: economical, financial, social, technological, etc. ones.

3. The synergy usually achieved when Research and Development are cybernetically related. This require to do both of them, mostly, in parallel and not in series, via a combination of Action-Research, Action-Learning, and Action-Design; all of which in the context of an incremental planning. For example, see Braybrooke& Lindblom (1970).

4. The **Trans-Disciplinary Communication** used in this project is a necessary condition for real life problems. Sometime inter-disiplinary communication is suffienct but sometime, like in this artcile it is necessary to have the skills for trans-discipplinary communication.

5. These skills are developed in consulting because the cliente (end user, manager, etc) may hardly communicate in a discilinary or inter-disiplinary semiotic systems.

6. The work briefy described in this extended abstract is good, probably even an ideal, example of what is Traslation Research and the huge benefits it may generate. As Marita G. Titler (2018)affirms,

   > Translation science is a relatively young area of investigation that is rapidly growing. … Translational research is a dynamic continuum from basic research through application of research findings in practice (Titler, 2018).

7. The work, briefly described in the extended abstract is a methodology, i.e., a set of related or relationable methods, which may be used and/or related (or not) according the action-learning and the research-learning process. This is typical of Systemic Methodology, especially when applied to relating Research and developments via cybernetic negative and positive feedback; which require developing both activities in parallel and not in series.

8. It is even a **meta-methodology** because it allows methodological design for its application in other contexts with other objective and other restriction.

9. This work is also a great example of relating Academy with Society at large via Industry, Trans-Disciplinary Communication, and relating adequately, professionalandmanagerial experience with scholarly knowledge. The later means that it represents a methodology relating appropriately explicit, implicit, and tacit kinds of knowledge (real life experience and scholarly explicit knowledge).

10. It evident, from the above summarized 9 points, that the methodology used by the authors is complex and adaptable. As complex, it has emergent properties which are not present in any of its parts (related methods). It is adaptable because it has the "requisite variety" as Ashby (1956) named it in the First Law of Cybernetics..

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