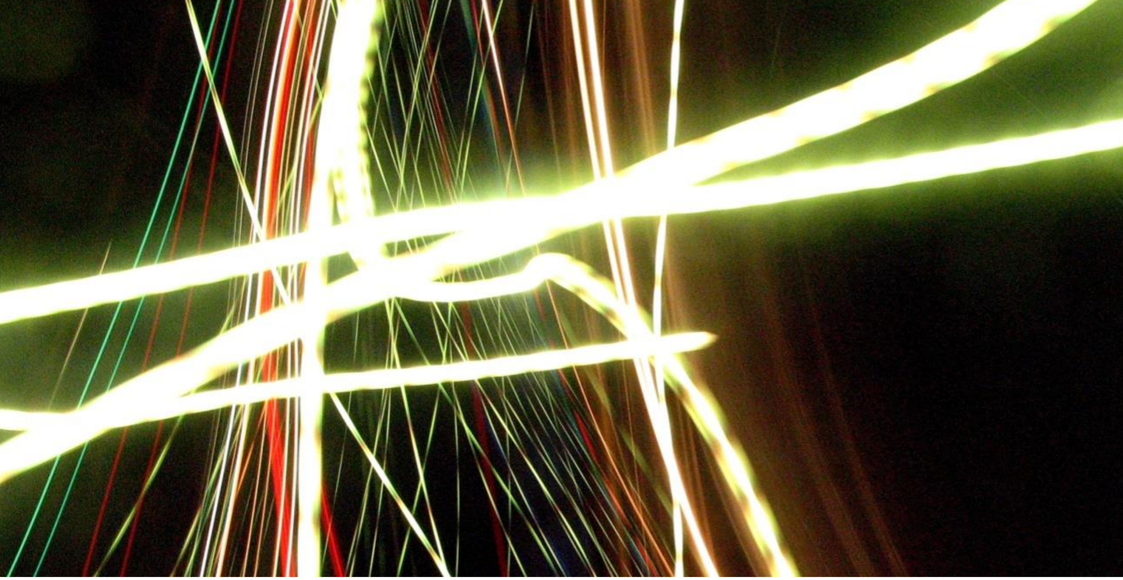

Tagungsband ComForEn 2018

9. Symposium Communications for Energy Systems

„Blockchains für das Energiesystem?“

1. und 2. Oktober 2018

Fachhochschule Salzburg

5412 Puch/Salzburg, Salzburg, Österreich

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9. Symposium Communications for Energy Systems

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Inhalt

Vorwort

Das Thema Blockchain hat große Aufmerksamkeit auf sich gezogen. Ein vielschichtiges Gemenge ist entstanden, das aus Fragen verteilter Systeme, Fragen rund um neue Geschäftsmodelle, Fragen der Regulierung und nicht zuletzt Fragen nach pragmatischer technischer Realisierung besteht. Die ComForEn 2018 zum Ziel, abseits von Inszenierungen und Hype ein fachliches Austauschforum für die österreichische und europäische Forschungscommunity mit dem Schwerpunkt Blockchain-Pilotprojekte zu sein. Der Fokus liegt auf Diskussion rund um die Fragen in welchen Anwendungsfällen eine Blockchainlösung Sinn macht, wie der tatsächliche Stand der Technologieentwicklung aussieht und welche Umsetzungsprojekte es in Österreich gibt, bzw. was deren erste Schlussfolgerungen sind. Darüber hinaus werden in gewohnter Weise Ergebnisse aus laufenden Projekten auch abseits der Blockchain ausgetauscht.

Das AIT Austrian Institute of Technology GmbH, die FH Salzburg, der OVE und die GMAR laden Sie herzlich ein, mit ExpertInnen aus Forschung und Industrie die weiteren Herausforderungen auf dem Weg zu einem nachhaltigen Energiesystem zu diskutieren.

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Dominik Engel
Leiter des Zentrums
für sichere Energieinformatik
an der FH Salzburg

Wir danken dem Organisationsteam

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Symposium Tag 1

Blockchain-Umsetzungen in Österreich

Decentralized Storage Battery Management: A Tale of Two Blockchains

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Abstract – In cooperation with Siemens Österreich AG and Energienetze Steiermark GmbH, AIT has evaluated Blockchain technologies for the specific use case of local decentralized battery storage management. Evaluation criteria were defined, and several Blockchain implementations were considered in light of these criteria. As a result, a primary Proof-of-Concept was implemented based on Ethereum and tested in laboratory conditions. A second alternative implementation based on Tendermint was tested on a single machine using containerization. This paper documents the test implementations and reports some preliminary observations resulting from these tests.

1. Introduction

Blockchains are presently being discussed very heavily not only in technical circles, but in popular culture and media as well. One reason for this is the success of Bitcoin [1], a virtual currency based on Blockchain technologies that has been on-line since 2009, proving the feasibility and robustness of the concept. Less-deserved reasons for this hype however were the asset bubbles inflated by numerous cryptocurrencies (including Bitcoin) in early 2018, which have nothing to do with the fundamental usefulness of Blockchains.

Blockchain technologies allow a network of participants, who do not necessarily trust one another, to share a common, agreed-upon history of transactions. In recent years, Blockchain has gained enormous attention and is now regarded as being a highly interesting, possibly disruptive [2] technology for business and use cases that go beyond financial transactions. Many start-ups, enterprises, governments and research institutions are currently exploring application scenarios across in areas such as health care [3], electronic voting [4], electronic marketplaces [5], supply chain management [6], and energy networks or microgrids [7].

2. Use Case: Decentralized Battery Management

In the field of energy systems, the primary applications are in the field of energy trading, including conventional trading processes but also direct trading between prosumers (peer to peer energy trading). While this is still challenging in the current regulatory regime, the setup of incentive systems in parallel to established business processes if easy to realise in practise. In general, due to a high level of automation provided by distributed ledger technologies, small or "micro transactions" are generally more viable than in a conventional trading setup.
Currently, there are only very few projects that focus on (distribution) grid management. Here, potential application areas can be resource sharing among multiple players (such as grid resources or charging stations), virtual power plants or flexibility platforms. The EnerChain project [8] is an example that provides a deal-matching platform for gas trades using a Blockchain approach. Another example is the Brooklyn Microgrid project[1], which allows neighbours to exchange energy produced by their own photovoltaic cells (PVCs).
The AIT proof-of-concept implementation is less ambitious; in this case, a Blockchain component is deployed in order to measure the real-time energy consumption and PVC production by consumers and combine this information with weather forecasts in order to control a shared local storage battery.

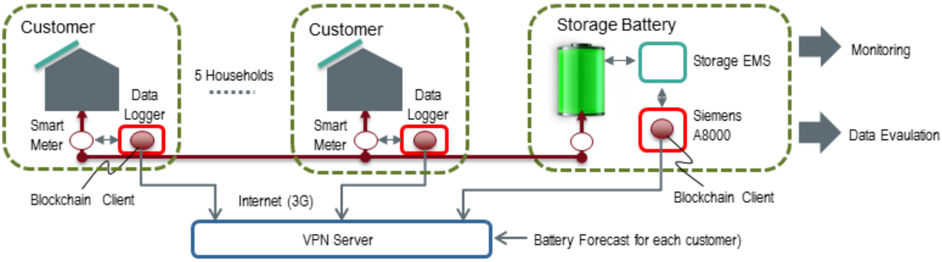

Figure 1. Battery Management Use Case Proof-of-Concept Architecture

This pilot is conceived to be compatible with existing facilities and unobtrusive to the customer. Referring to Figure 1, the functions of energy consumption monitoring (through the Data Logger) and communication (through the Blockchain Client) are combined on Intel NUC PCs and deployed on the client's premises, where they connect with a VPN server over standard commercial mobile broadband components. In this way, the only wired connection required on-site is a power outlet. In the future, the Blockchain client could be integrated with other previously deployed components, such as the Smart Meter or the photovoltaic installation itself [9]. The Data Logger communicates with the Smart Meters over the Wireless M-Bus

[1] https://www.technologyreview.com/s/604227/blockchain-is-helping-to-build-a-new-kind-of-energy-grid/
Accessed on 2018-09-13

standard[2] and with the Blockchain client through a local API. An algorithm running on the Blockchain takes the measurements from the Data Logger, combines them with the provided forecast data, and computes a set-point for the storage battery, which reads the set-point value from its own local Blockchain client, running on a Siemens A8000 controller.

3. Evaluation of Blockchain Technologies

In order to determine which Blockchain implementation to integrate with the Proof-of-Concept, a number of stakeholder workshops were held. The result of these workshops was first a definition of evaluation criteria, and then an evaluation of several different implementations based on those criteria. Practical discussions of grid management-related use cases revealed that Ethereum[3], Hyperledger Fabric[4] and Tendermint[5] are the three best-fitting candidates for a solution development given the current state of the technology landscape. A selection of criteria and their evaluation for these implementation is given in Table 1.

Table 1: Blockchain Implementation Evaluation Criteria

Criterion	Ethereum	Fabric	Tendermint
Supported operating systems	Windows, Linux	Linux	Windows, Linux
Transaction rate and latency	15 Tps/30s	3500 Tps/1s	10.000 TpS/1s
Maturity and stability	High	Medium	Low
Support for Smart Contracts	Yes (Solidity)	Yes (Golang)	Not comparable
API Support	Multiple	Multiple	Developer supported
License model	GPLv3	ApacheV2	ApacheV2
Consensus mechanism	PoW, PoA	Kafka ordering	PBFT
Documentation and community	Medium/High	High/Medium	High/Low
Support for private networks	Yes	Only	Only

Ethereum was designed for public (permissionless) deployment and thus relies on the more secure "Proof of Work" (PoW) consensus mechanism, although recently a "Proof-of-Authority" (PoA) mode for private networks has also been released. PoW is characterized by high energy consumption, low transaction rates and high latency. However, due to its high level of maturity and designed support for Smart Contracts, Ethereum was chosen for the Proof-of-Concept implementation.

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[2] http://standards.cen.eu/dyn/www/f?p=204%3A110%3A0%3A%3A%3A%3AFSP_PROJECT%2CFSP_ORG_ID%3A34339%2C6275&cs=164AF65D6C490397FDBD2D8E475128720
Accessed on 2018-09-13

[3] https://github.com/ethereum/go-ethereum

[4] https://github.com/hyperledger/fabric

[5] https://github.com/tendermint/tendermint

Due to the lack of Linux support for the deployed M-Bus driver, Hyperledger Fabric was excluded from the Proof-of-Concept evaluation. It should also be noted that the present version of Fabric (V1.2) only supports the Kafka ordering service as a consensus mechanism, which means that it is not fully decentralized. Support for Byzantine Fault Tolerance (BFT) is pending, but no date has been set[6].

Tendermint provides an interesting contrast to Ethereum, in that it was developed specifically for private (permissioned) networks and implements a variation of BFT known as Practical Byzantine Fault Tolerance (PBFT) [10]. It can support the highest transaction rate of the evaluated technologies but is known to suffer from scalability problems when the number of nodes in the private network becomes large. This is due to the large number of encrypted messages that must be exchanged between nodes of a PBFT network. Nonetheless, it was decided to also test Tendermint, based partially on the fact that the EnerChain and Brooklyn Microgrid projects are also based on this technology.

4. Proof-of-Concept Implementations

Ethereum was chosen as the primary implementation framework, and this Proof-of-Concept was extensively tested in a laboratory environment, including robustness against network and electricity outages for individual components. The Tendermint implementation was tested only on a single machine using Docker containerization for the test nodes. Nonetheless, this alternative provided a useful contrast to the primary implementation.

4.1 Ethereum Implementation

The deployment architecture for the Ethereum implementation is shown in Figure 2. In this case, each customer node runs an instance of *geth* (go-ethereum, the reference implementation implemented in Golang) that acts as a “Miner,” that is, a participant in the Proof-of-Work consensus network. Ethereum miners have the task of validating and ordering all transactions.

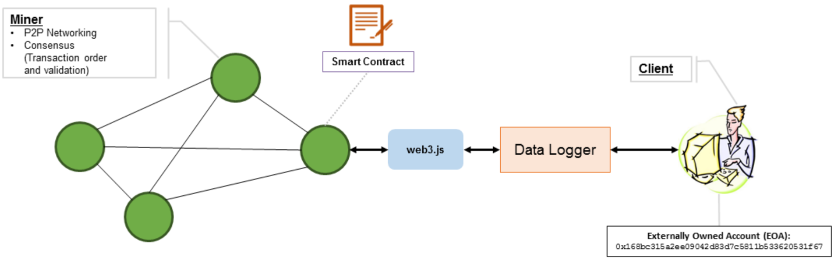

Figure 2. Proof-of-Concept Ethereum Architecture

[6] https://hyperledger-fabric.readthedocs.io/en/release-1.2/Fabric-FAQ.html?highlight=BFT

At the same time, the business logic of the battery storage was developed as a Solidity program, compiled to bytecode for the Ethereum Virtual Machine, and deployed the Ethereum network (as a so-called *Smart Contract*). This means that a copy of the Smart Contract was distributed to every node and executed on each node independently. The functions of the contract are validated and committed only if each node computes exactly the same result, thereby achieving consensus. Input from the consumer's Smart Meter, which is identified by a so-called "Externally Owned Account" derived from a cryptographic key, is provided through the Data Logger and interacts with the Blockchain through an API (web.js or similar). The execution of the Smart Contract is triggered by signals coming from the A8000 node (also an Ethereum client node) in the test network.

4.2 Tendermint Implementation

While Ethereum was developed specifically for Smart Contracts, Tendermint is more a general purpose blockchain consensus engine that enables distributed replicated state machines. Transactions represent state transactions and hence any new node can be synchronized with a private Tendermint network by replaying the transaction history against a local copy of the state machine. The deployment architecture for the Tendermint implementation is shown in Figure 3. Here it can be observed that a participating member of the network, a so-called "Validator Node," runs two independent components: first, the Tendermint Core, which is responsible for peer-to-peer networking and transaction ordering, and second, the application (App), which is responsible for transaction validation and business logic.

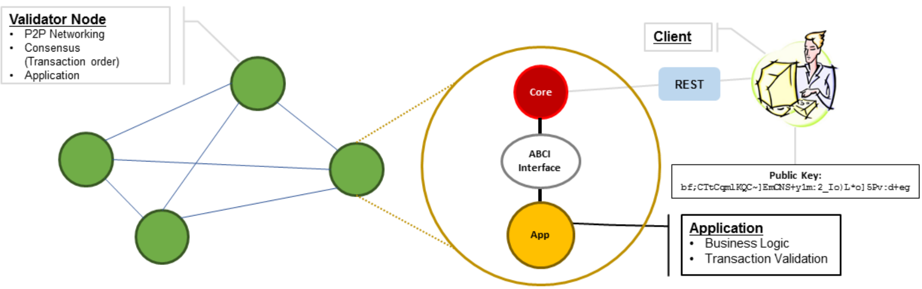

Figure 3. Proof-of-Concept Tendermint Architecture

The App communicates with the Core through a special protocol known as the Application Blockchain Interface (ABCI) The advantage of this approach is that the application can be developed in any programming language (Python was chosen for this Proof-of-Concept implementation). Transactions sent by a client, who in this case is identified by a public encryption key rather than a derived address, are sent directly to a REST interface of the Core (not the App). The Core transmits all transactions to the App, which confirms their validity by first determining that the encrypted Smart Meter measurement does indeed derive from a known customer and checking that the measurements are within allowed physical ranges. Once the App has declared the transaction to be valid, the Core ensures that the transaction is distributed to all nodes and committed to the local transaction history. At that point the business logic in the App is triggered, and the battery management calculations are carried out – this time implemented in Python rather than Solidity.

5. Conclusions and Next Steps

In general, Blockchain implementations carry a number of risks, technical and otherwise. Trust within the Blockchain itself is enforced by consensus protocols, but all interfaces with the outside world, such as the import of Smart Meter data, rely on external trust interfaces upon which a Blockchain application relies but cannot enforce. Blockchains introduce additional risks in terms of complexity, such as the management and deployment of Smart Contract Code, and scalability, especially when higher transaction rates and low latencies are required.

Tests with the Ethereum Blockchain demonstrated some of the drawbacks of deploying Ethereum in a private network. Attempts at using the Proof-of-Authority consensus mechanism failed due to unrecovered blocking, possibly caused by intermittent 3G network connectivity. Switching to Proof-of-Work improved stability but introduced complications regarding gas price and availability for the execution of the underlying Smart Contract.

The Tendermint implementation demonstrated better stability under network drop-outs, at least to the extent that they could be simulated on a single machine. This is probably due to the PBFT algorithm, which is designed to tolerate drop-outs (or indeed falsified transactions), although no transactions are processed during the drop-out period. However, although Tendermint does not rely on Smart Contract compilation and deployment in the was that Ethereum does, it is still faced with the difficulty that any changes to the business logic must be simultaneously deployed to each node before the system can run again.

The preliminary research reported in this paper will be continued in the Austrian FFG Project "GrEnLa Blockchain Grid," due to start in November 2018. In that project, additional use cases such as peer-to-peer energy trading and local energy auctions will be considered, and the tests will be moved from the laboratory to limited field deployment.

Acknowledgements

Das Projekt „Green Energy Lab - Blockchain Grid" wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Programms „Vorzeigeregionen Energie" durchgeführt

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Blockchain im Innovationslabor act4.energy

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Abstract – Blockchain-Anwendungen können einen wesentlichen Beitrag zum Aufbau zukünftiger, dezentraler Energiesysteme leisten und neue digitale Geschäftsmodelle ermöglichen. Innovative Anwendungen der Blockchain im Energiebereich werden im Innovationslabor act4.energy in einem Living-Lab Testbetrieb unter realen Bedingungen getestet und unter Einbindung von NutzerInnen in einem Co-Creation Prozess weiter entwickelt. Derzeit werden vor allem Anwendungen für das Crowdinvest von PV-Beteiligungsanlagen, des Peer-to-Peer Tradings sowie interaktionslose Lade- und Bezahlvorgänge für E-Fahrzeuge im Innovationslabor entwickelt. act4.energy betreibt dazu in Kooperation mit der lab10 Collective eG zukünftig einen Knoten im ARTIS Blockchain Netzwerk und stellt weitere Infrastruktur, wie z.B. eine E-Mobility Operation Plattform und ein Demand Site Managementsystem (Flexibilitätenhandel) zur Verfügung.

1. Das Innovationslabor act4.energy

act4.energy ist ein vom österreichischen BMVIT über das Programm „Stadt der Zukunft“ gefördertes Innovationslabor, das seit Jänner 2018 experimentelle Umgebungen errichtet und betreibt und damit die Rahmenbedingung für Innovationen schafft. Im Innovationslabor werden Forschungs – und Innovationsprojekte bei der Entwicklung und Erprobung von neuen Produkten, Lösungen und Dienstleistungen zur Verbesserung der Nutzung von erneuerbaren Energien begleitet. Forschung wird dabei praxisnahe gestaltet und NutzerInnen werden im Sinne eines Open Innovation und Co-Creation Ansatzes in die Innovationsprozesse unmittelbar einbezogen. Themenschwerpunkte sind dabei die Schaffung eines regionalen Energiesystems auf Basis von PV-Strom (Eigenverbrauchsoptimierung), die Bewerkstelligung der Sektorenkopplung (Strom, Wärme und Mobilität) sowie die Forcierung der E – Mobilität.

1.1 Entwicklung zukunftstauglicher Energiesysteme

Klimaschutz, Nachhaltigkeit, Versorgungssicherheit – das sind ein Teil der Anforderungen an unser zukünftiges Energiesystem, die jedoch mit den bestehenden Strukturen aus fossilen Primärenergieträgern, zentral verwalteter Infrastruktur und zum Großteil nicht-digitaler Geschäftsmodelle nur schwer umzusetzen sind. Im Innovationslabor act4.energy wird daher – so wie in vielen anderen Initiativen und Forschungsprojekten – daran gearbeitet diese bestehenden Strukturen zu verändern und zu verbessern um ein neues, zukunftsfähiges Energiesystem zu gestalten. Unsere Vision dieser Zukunft ist digital, dezentral und zu 100% erneuerbar.

Ein Umbau unseres Energiesystems ist dabei in einem Gesamtkontext zu denken: Strom, Wärme, Kälte, Mobilität, Industrieprozesse – das alles soll in Zukunft aus klimaneutralen, umweltschonenden, erneuerbaren Energieträgern gespeist werden und dabei über möglichst dezentrale, gegenüber zentralen Fehlerquellen weitgehend immune Verteilnetze versorgt und über vorwiegend digitale Geschäftsmodelle vermarktet werden.
Auf dem Weg zu dieser Transformation sind aber noch einige Hürden zu überwinden. Als zentralen Leitfaden für Projekte und Aktivitäten im Innovationslabor haben wir diese Herausforderungen auf dem Weg in die Energiezukunft zu den „6 act4.energy Challenges“ zusammengefasst.

1.1.1 Die 6 act4.energy - Challenges

Die 6 act4.energy - Challenges sind die aus unserer Sicht wesentlichen Herausforderungen die auf dem Weg zu einem auf erneuerbaren Energieträgern basierenden, regionalen, digitalen und global duplizierbaren Energiesystem gelöst werden müssen. Diese Herausforderungen sind:

- **Volatilität** der Energieträger
- **Dezentralisierung** der Versorgung
- **Ganzheitlichkeit** über Sektoren, Branchen und Länder hinweg
- **Benutzerfreundlichkeit** für Konsumenten, Erzeuger und Dienstleister
- **Wirtschaftlichkeit** für Konsumenten, Erzeuger und Unternehmen
- **Zuverlässigkeit** in Versorgung und Betrieb

Volatilität: Erneuerbare Energieträger sind volatil – d.h. ihr Ertrag ist nicht gleichmäßig sondern zu unterschiedlichen Tages – und Jahreszeiten unterschiedlich ausgeprägt. Ein Energiesystem, dass zu wesentlichen Teilen aus erneuerbaren Energieträgern gespeist wird, muss der Volatilität in der Erzeugung dieser Energien Rechnung tragen.

Dezentralisierung: Zukünftige Energiesysteme müssen kleinzellig aufgebaut sein und Energie wird möglichst nahe dort verbraucht werden wo sie erzeugt wurde. Wir stehen vor der Herausforderung unser Stromnetz von einer hierarchischen Struktur in eine Art Bienenwabenstruktur, aus für sich weitgehend abgeschlossenen Zellen umzubauen und große, überregionale Verteilnetze durch regionale Strukturen bestmöglich zu entlasten.

Ganzheitlichkeit: Energiemanagementsysteme müssen in Zukunft möglichst viele Teilbereiche erfassen und sinnvoll miteinander verknüpfen. Dabei sind nicht nur Strom sondern auch Wärme/Kälte, Mobilität und Industrieprozesse zu berücksichtigen.

Benutzerfreundlichkeit: Die Energiesysteme werden in Zukunft hochgradig vernetzt und automatisiert sein, und viele Funktionen werden im Hintergrund von intelligenter Software gesteuert. Dennoch müssen diese Systeme für NutzerInnen verständlich und bequem bedienbar sein, so dass sinnvolle Lösungen auch schnell von einer breiten Anwenderbasis akzeptiert werden.

Wirtschaftlichkeit: Alle neuen Systeme, Produkte und Dienstleistungen müssen sich auch wirtschaftlich rechnen und ein Markt dafür muss gegeben sein. Technische brillante Lösungen, die niemand zahlen kann oder will, tragen nichts zu einem zukunftsfähigen Energiesystem bei.

Zuverlässigkeit: Alle unsere Energieverbraucher werden in Zukunft in komplexen, über das Internet vernetzten Systemen verbunden sein. Wir stehen damit vor der Herausforderung Datenschutz, Schutz vor Cyberattacken und vor allem die Betriebssicherheit und den Ausfallschutz sowohl auf der Anlagenebene aber auch auf der digitalen Ebene von Anfang an mit zu berücksichtigen.

Das Energiesystem muss trotz Volatilität der Erneuerbaren die Energieversorgung zu jeder Zeit sicherstellen, nicht hierarchisch-zentral sondern regional-dezentral strukturiert sein und komplexe und über verschieden Sektoren gekoppelte Systeme Energie für bequeme, einfach zu bedienende, sichere und wirtschaftlich profitable Produkte und Dienstleistungen zur Verfügung stellen.
Die im Innovationslabor act4.energy durchgeführten Innovations- und Forschungsprojekte tragen Erkenntnisse und Teillösungen zu diesen 6 Challenges bei und bilden damit Mosaiksteine aus denen sich Schritt für Schritt das Bild für eine klimaneutrale, ökologisch nachhaltige, benutzerfreundliche und bezahlbare Energiewende ergibt.

1.1.2 Forschungs- und Innovationsinfrastruktur

Um die Herausforderungen der 6 Challenges Schritt für Schritt zu lösen bietet das Innovationslabor act4.energy Forschungspartnern eine Living-Lab Testumgebung im Südburgenland, einer Region im Südosten Österreichs. Es wird mit dem Fokus auf einen Open-Innovation und Co-Creation Ansatz, der Zugriff auf die durch Projekte und die Geschäftstätigkeit unserer Trägerorganisation geschaffene Infrastruktur (installierten Anlagen, Verbrauchern und Objekten mit einem bestehenden NutzerInnen-Zugang) ermöglicht.

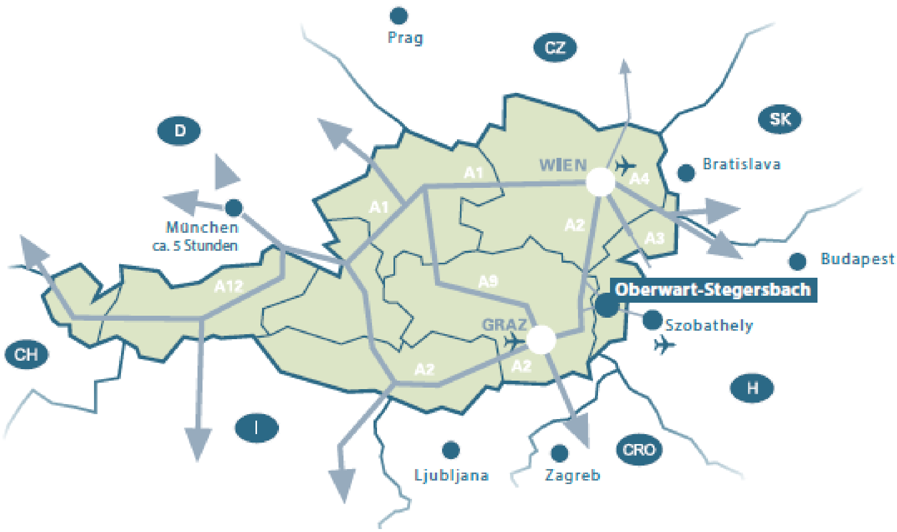

Abbildung 1. Die Innovationslabor-Region im Südosten Österreichs

Zur verfügbaren Infrastruktur gehören unter anderem mehr als 400 installierte PV – Anlagen (gewerblich, kommunal, privat und Gemeinschaftsanlagen), ein E-Car Operation Center mit angeschlossener Ladeinfrastruktur, ein virtuelles Kraftwerk (Demand Site Management System), zwei Speichercluster sowie ein Blockchain-Node.

2. Blockchain im Innovationslabor

Blockchain – Anwendungen im Energiebereich haben das Potential einen wesentlichen Beitrag zur act4.energy-Challenge der Dezentralisierung zu leisten und bilden damit einen Fokuspunkt in der Arbeit des Innovationslabors. Dabei geht es uns, ganz im Sinne des Co-Creation Gedankens, vor allem um praxisorientierte Forschung, die die Entwicklung und Erprobung von innovativen Dienstleistungen und Geschäftsmodellen in den Mittelpunkt stellt.
Im Innovationslabor findet daher keine Grundlagenarbeit, wie z.B. die Entwicklung eines neuen Blockchain Protokolls statt, wir konzentrieren uns vor allem darauf wie man innovative Blockchainanwendungen möglichst nahtlos und für die NutzerInnen einfach zu bedienen in das Energiesystem implementieren und damit z.B. Lösungen für den Aufbau von Local Energy Communities gestalten kann. Es geht uns hier auch um Bewusstseinsbildung, dass Blockchain sehr viel mehr ist als Kryptowährungen und die damit verbundene Medienaufmerksamkeit um Kurssteigerungen – und Abstürze.

2.1 Betrieb eines Blockchain-Node im ARTIS Projekt

Der Betrieb und die Bereitstellung von Forschungsrelevanter Infrastruktur zum Implementieren und Testen neuer Technologien im Energiebereich ist eine Kernaufgabe des Innovationslabors, der Betrieb eines Blockchain-Node daher ein logischer Schritt. Dazu sind wir eine Kooperation mit der als Genossenschaft organisierten lab10 Collective eG gepflegt, um die beiderseits verfügbaren Kompetenzen zu bündeln und damit einen „Blockchain-Kompetenzhub“ mit Fokus auf dem Einsatz der Blockchain-Technologie in der Energiewirtschaft zu schaffen.

Die von lab10 entwickelte Blockchain ARTIS basiert auf der Technologie die mit Ethereum entwickelt wurde und ist als unabhängiges Netzwerk aufgebaut. Neue Funktionalitäten wie „Streaming Money“ und „Anonymous Human Registration“ werden darin implementiert und in Projekten im Innovationslabor getestet um einerseits die Serviceindustrie zu beflügeln und zur Ressourcenschonung beitragen und andererseits vom Netzwerkeffekt registrierter Mitglieder zu profitieren. Die gesamte Software wird als Open-Source zur Verfügung gestellt und die Interaktion mit dem System und die Coinverteilung erfolgt über die ebenfalls von lab10 entwickelte die Minerva App.

Im Rahmen dieser Kooperation wird act4.energy einen ARTIS Node betreiben und die Erprobung von Blockchain-Entwicklungen für Energieanwendungen in einem Lviving-Lab Testbetrieb ermöglichen und unterstützen.

2.2 Projekt SonnWende+

Als eines der ersten im Innovationslabor act4.energy durchgeführten Projekte analysiert SonnWende+ Blockchain-Technologie im Kontext erneuerbarer elektrischer Einspeisung und Flexibilität. Ziel ist die Erforschung neuer und effizienter Lösungen für Energiemanagement-Services und Energiehandel.

Unter der Konsortialführung des AIT (Austrian Institute of Technology) mit den Projektpartnern lab10 collective eG und dem Energieinstitut an der Johannes Kepler Universität Linz soll in der Innovationslaborumgebung ein Ökosystem geschaffen werden, in dem Nachfrager und Anbieter von Energiedienstleistungen in Co-Creation-Prozessen neue Lösungen für PV-Strom-Eigenoptimierung auf Mehrfamilienhaus-, Quartiers- und regionaler Ebene entwickeln und testen können. Ziel des Projektes ist es die Möglichkeiten der Blockchaintechnologie hinsichtlich der Automatisierung der Transaktionen und Abrechnung von Zahlungsflüssen zu untersuchen und erproben und damit den organisatorischen Overhead auf ein Minimum zu reduzieren.

Im Zuge des Projektes wurden drei Use-Cases definiert in denen Blockchainanwendungen im Innovationslabor getestet und mit NutzerInnen aus der Innovationslaborregion evaluiert und weiter entwickelt werden. Diese drei Anwendungsfälle – die Implementierung eines Energiekontos, das berührungslose Laden von E-Fahrzeugen und die Abrechnung von crowdfinanzierten PV-Beteiligungsprojekten – wurden so ausgewählt, dass dabei wesentliche Vorteile der Blockchaintechnologie zur Geltung kommen. Ein vierter Use-Case, peer to peer trading, wird im Zuge des Projektes simuliert werden.

Das Projekt SonnWende+ wird auch im Beitrag dieses Tagungsbandes „Blockchain-based solutions in energy communities and the significance for Austrian energy stakeholders“ von Mark Stefan und Tanja Tötzer genauer vorgestellt.

2.3 Ausblick

Aufbauend auf den Ergebnissen aus dem SonnWende+ Projekt ist die Weiterentwicklung der dort untersuchten Anwendungsfälle geplant.

Im Bereich der E-Mobilität wird die Entwicklung von weitgehend interaktionslosen und anonym möglichen Lade – und Bezahlvorgängen auf Basis der ARTIS Blockchain und der Minerva-App weiter gearbeitet. Ziel ist hier die Entwicklung eines einfachen, in die Bordsysteme des Fahrzeugs integrierten Bezahlvorgangs, der synchron mit dem Ladevorgang läuft und vom User außer einer einfachen Bestätigung keine weiteren Interaktionen erfordert.

Danksagung

Das Innovationslabor act4.energy wird über das Programm "Stadt der Zukunft".[7] vom österreichischen Bundesministerium für Verkehr, Innovation und Technologie gefördert. Das Projekt „Innovationslabor act4.energy" wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Programms „Stadt der Zukunft" durchgeführt

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Ing. Andreas Schneemann, MSc. besuchte den Ausbildungszweig Steuerungs- und Regelungstechnik an der HTBLA in Pinkafeld und absolvierte an der Donau Uni Krems und der Alpen-Adria-Uni Klagenfurt den Universitätslehrgang Energy Autarchy Technology and Implementation, welchen er mit dem akademischen Grad Master of Science abschloss. 2005 gründete Andreas Schneemann sein erstes Unternehmen und leitet heute eine Unternehmensgruppe im Bereich der Energie- und Ingenieursdienstleistungen und Beratung. Andreas Schneemann ist Eigentümer der Trägerorganisation und Initiator des Innovationslabors act4.energy

Dipl.-Ing. Michael Niederkofler studierte technische Physik an der TU Graz und schloss sein Studium dort 2003 ab. Einen Großteil seiner beruflichen Laufbahn verbrachte er als Projektleiter für Großprojekte im Anlagenbau im Ausland und lebte unter anderem in Venezuela, Kasachstan und China. Nach mehreren Jahren als Geschäftsführer in China machte sich Michael Niederkofler als Berater mit den Schwerpunkten Internationalisierung, Projektmanagement und Strategieentwicklung selbständig. Seit Jänner 2018 ist er Leiter des Innovationslabors act4.energy.

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[7] Stadt der Zukunft ist ein Forschungs- und Technologieprogramm des Bundesministeriums für Verkehr, Innovation und Technologie. Es wird im Auftrag des BMVIT von der Österreichischen Forschungsförderungsgesellschaft gemeinsam mit der Austria Wirtschaftsservice Gesellschaft mbH und der Österreichischen Gesellschaft für Umwelt und Technik ÖGUT abgewickelt.

Blockchain-based solutions in energy communities and the significance for Austrian energy stakeholders

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Abstract – Within the research project *SonnWende+* the application of the blockchain technology is investigated in dedicated use cases in the innovation lab *Energy Innovation Cluster Südburgenland* with the focus on renewable energy sources and flexibility services. The goal is to find new and efficient blockchain-based solutions for services in energy management and trading on a local level. Innovative methods for maximizing the self-consumption of photovoltaic generation within a building, quarter, and region will be developed. Additionally, co-creation workshops with participants of the local communities and a survey among energy stakeholders isperformed to collect inputs and ideas for the application development as well as experiences within the validation phase for further improvements.

1. Introduction

The continuous integration of renewable energy sources in distribution grids leads to challenges for the technical and economical energy system - in particular, costs of the renewable energy technologies, the integration of distributed generation, and its volatility. Within the research project *SonnWende+*[8] the blockchain technology in the energy domain is investigated with the aim to over overcome the previously mentioned challenges. Furthermore, new concepts and applications are developed and validated in the innovation lab *Energy Innovation Cluster Südburgenland* within a real environment.

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[8] Projekt partners:
AIT Austrian Institute of Technology GmbH (Project lead)
lab10 collective eG
Energieinstitut an der Johannes Kepler Universität Linz

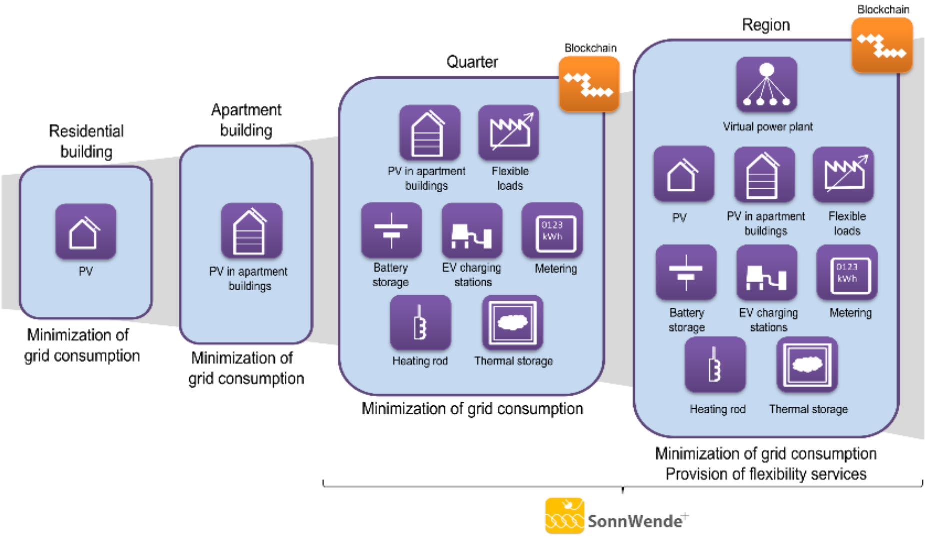

Figure 1. Scope of SonnWende+: Reduction of grid consumption and provision of flexibility services in quarters and regions.

1.1 Challenges

One of the key challenges is the accounting of relatively small amounts of energy, currently recorded and cleared with high effort. The already very low profitability is further decreased due to additional administrative effort. The blockchain technology represents a new approach with high automation degree within a secure environment. Due to this high degree auf automation especially in transactions and accounting, the effort could be increased to a minimum and thus, also resulting in much lower costs. Additionally, security aspects regarding sensitive user data are ensured and can be further increased.

1.2 Scope of the project

Within the project *SonnWende+*, several concrete use cases – based on the blockchain technology – are defined, especially for quarters and regions. Some of them will be analyzed only on a conceptual level or based on simulations, others will be implemented in the innovation lab and tested in a real environment. Beside the technical issues, regulatory conditions when using the blockchain technology (e.g., for energy trading between private customers) are analyzed and recommendations elaborated. Stakeholders and users are integrated in decision processes in project workshops to collect their ideas, perceptions, and experiences which will be considered in the development of applications and their improvements within the validation phase.

Figure 1 gives an overview about the scope of the *SonnWende+* project, whereas the main focus is on the integration of the blockchain technology in quarters and regions using existing technologies (e.g., photovoltaic in residential and apartment buildings, charging stations for electric vehicles) and methods (e.g., optimization/minimization of grid consumption).

1.3 Innovation lab

The innovation lab provides a real environment for testing the blockchain solutions and consists of a virtual power plant including a storage cluster, photovoltaic systems, and flexible loads. In addition to the electric side, a coupling to the heat sector and mobility sector via public and private charging stations for electric vehicles will be crated. In this context, various applications based on blockchain technology are getting possible, such as benefit schemes for energy carrier comprehensive local produced energy, internal pooling of the virtual power plant, and dynamic usage of photovoltaic systems by several tenants.

1.4 Blockchain technology and its potential

The blockchain technology was introduced in 2008 serving as technology base for Bitcoin [1]. Within the first years it was only known by technology insiders already recognizing its potential. When introducing Etherium [2] as new blockchain platform, it was foreseeable that this technology will cause substantial changes in the existing financial system [3] as well as in various economical and organizational structures [4].

In comparison to existing technologies and methods, blockchain provides mechanisms for performing immediate and secure accounting for received and supplied energy between machines without any additional interaction or interfaces resulting in a high potential to arrange the energy market efficient and decentral [5].

2. SonnWende+ use cases

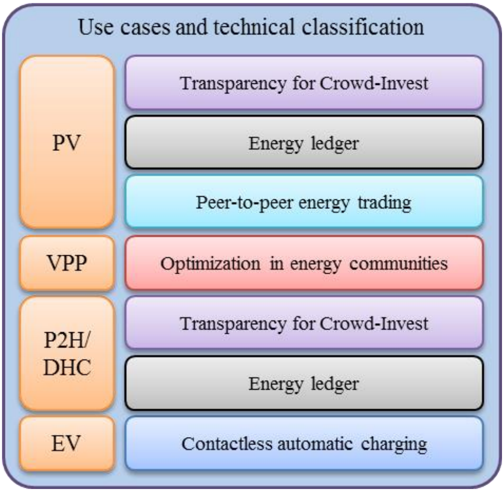

Figure 2 SonnWende+ use cases (e.g., energy ledger) and their technical classification (e.g., energy ledger will be used for pv generation as well as in the power-to-heat domain).

Figure 2 illustrates the project use cases and their technical classification – for example, the energy ledger will be implemented for PV generation as well as in the power-to-head domain. Some of the use cases will be implemented in the innovation lab (transparency for crowd-invest and energy ledger, both in the photovoltaic domain, contactless automatic charger). The optimization in energy communities is analyzed on a conceptual level with several scenarios in simulations. The following sections will provide an explanation of the used-cases.

2.1 Transparency for crowd-invest

The first use case covers an investment model for facilities (e.g., photovoltaic power plant, heat pump) by crowd-invest. House-owners provide their roof surface area, investors provide money for purchasing and installation of new facilities. These costs are rediscounted by the energy savings due to self-consumption or energy surplus. After complete clearance (including interest), the facility will pass into the ownership of the house-owner. The blockchain is used to provide an exact state of the erased and open costs to investors and house-owners in real-time.

2.2 Energy-ledger [6]

The second use case covers the introduction of an energy ledger which is very similar to typical systems in super markets (collecting points, which can be exchanged for benefits). The participants within the innovation lab can collect points by acting in an energy-efficient manner (e.g., optimization of self-consumption, installation of heat-pumps). The collected points are fictional and in no relation to any existing currency. Thus, they cannot be paid-out in cash but might be used to utilize benefits at other participating parties (e.g., lower energy costs at a charging station which is operated by the innovation lab as part of the community). Within the innovation lab, two clusters with 15 participants each will be available for the test mode and validation.

2.3 Contactless automatic charging

The third use case deals with contactless automatic charging of electric vehicles. Whenever a car stops at the infrastructure (integrated in the floor), an automatic charging process will be started until the battery is completely loaded (or until it reaches the user-defined level) or the car will start moving again. To enable this charging technique for the participants within the community, the adequate infrastructure will be implemented (e.g., in parking areas next to shopping centers) and validated within the project. Based on the blockchain technology, new smartphone applications will be developed, providing configurations and visualization of the energy transfer and the corresponding costs. A secure automatic payment will be guaranteed.

2.4 Peer-to-peer energy trading

This use case covers the peer-to-peer energy trade in local energy communities. In particular, it should be possible to enable the local trade between PV produces and interested consumers [7]. Each consumer can choose several PV producers based on their offered price. Additionally, the local energy provider covers the residual energy and can also be chosen by the consumers. The produced energy is monitored by Smart Meter and will be distributed in a fair manner to the customers. The clearing is done automatically by blockchain transactions. Based on price forecasts, the customers can operate their flexible loads in a cost-optimal way (e.g., charging of electric vehicles or home battery storage when cheat prices are available).

2.5 Optimization in energy communities [8]

This use case approaches the energy optimization within local energy communities. Therefore, a model is implemented representing a community with different households including photovoltaic power plants, battery storage systems, and grid connection. The households cooperate with the goal to maximize the self-consumption of the whole cluster of households including the self-organization as a virtual power plant offering flexibility services and following a given load-profile. Additionally, an ideal scenario is created as benchmark by using an optimization tool, aiming to minimize the costs of the community. Many other scenarios (e.g., integration of community storage) are created and compared to this baseline. Based on the outcomes, the feasibility of the blockchain technology in energy communities is evaluated.

3. Co-Creation in the SonnWende+ project

The various use cases described above illustrate the technological potentials of blockchain. However, further prerequisites must be given for a new technology to really prevail and lead to radical changes. For a technological transition, the role of society and the existing economic and technological system is central. Thus, in many cases stakeholders and users are actively involved in the development and implementation of new technologies. This co-creative process guarantees that innovations are aligned to real needs and have a high degree of user-friendliness. Besides, the assessment of decision-makers in the existing energy system and their attitude towards a new technology like blockchain also plays an important role in determining whether the energy industry will become a "first mover" in blockchain technology or how fast and in which areas this technology will develop and prevail. Exactly these aspects were researched in the Austrian-wide survey as part of the co-creation process in the *SonnWende+* project.

The survey of Austrian decision-makers from the energy industry relates to the German survey "Blockchain in der Energiewende", which was conducted by the German Energy Agency GmbH (dena) and ESMT European School of Management and Technology GmbH in July and August 2016 [5]. In addition to the actual survey results, this approach allows to estimate whether the opinion of the decision-makers has changed since the survey in 2016.

The method chosen was an anonymous telephone interview (CATI) conducted by a professional market and opinion research institute Kantar TNS. The survey was based on a questionnaire with ten questions, of which three questions were formulated as open questions without a given answer choice. The survey took place in April 2018 among 27 Austrian decision makers for energy management.

4. Survey results: Stakeholder assessment of the potentials of blockchain for energy management

The survey revealed that the Austrian energy stakeholders are already familiar with the topic of blockchain. This indicates that the level of awareness for blockchain has significantly risen since the German survey in 2016 where 31 % of respondents stated that they had not yet heard of blockchain applications in the energy sector. Most of the activities in this field are rather small niche projects (<100.000 Euro), not yet ready for market launch which indicates a certain risk awareness among the stakeholders towards this new technology. The high computational and energy demand was seen as biggest barrier and risk of blockchain, followed by a lack of expertise and a lack of customer acceptance. This survey result indicates that in addition to a technical improvement and an increase in the efficiency of the blockchain technology itself, there is a need for information and research or implementation in order to build up know-how in the use of blockchain technology among stakeholders and users.

In addition to the barriers and risks, the stakeholders see high potentials for the energy industry through blockchain. Particularly in the field of charging management for e-mobility radical changes and a successive diffusion are expected. Further high potentials are seen in new forms of energy trading such as peer-to-peer trading and trading platforms at the rule energy market as well as in grid management (establishment of microgrids, use of decentral, distributed flexibilities such as battery storage). The greatest skepticism among the stakeholders was found in the use of blockchain to finance energy infrastructure such as crowdsourcing for energy generation facilities, storages, etc. Here, the majority of respondents believe that it will remain a niche application or will not prevail.

Generally, about one fifth of respondents expect radical changes through blockchain in the energy sector, half of those surveyed see a successive diffusion, another fifth only niche applications, and 7 % no potential for blockchain. This roughly corresponds to the results of the German blockchain survey, although, a slight decline in the positive assessment of blockchain technology can be seen. The share of respondents considering a successive diffusion as likely declined, whereas the percentage of stakeholders seeing blockchain only as a niche application or without potential slightly increased.

Basically, the majority of decision-makers see no need for changing the existing framework conditions and consider them as sufficient and appropriate. The other respondents who expressed a demand for change, relatively frequently called for more clarity (such as liability) and adaptation in the regulatory and legal framework conditions. Furthermore, the topic of interoperability and the creation of standardized interfaces was mentioned. The survey does not provide a consistent picture of whether it requires more or less control. Some argue that more governmental supervision is needed, others want a more flexible and open system. Basically, the core characteristic of a blockchain is that a central, responsible instance is missing as an intermediary. However, for a broader market introduction of blockchain in the future it will be essential to clarify legal issues like e.g. how smart contracts can be embedded in existing laws regarding liability and jurisdiction.

5. Conclusion

In summary, the survey shows that the topic of blockchain has arrived in the energy industry. The energy companies are dealing with this issue and are already carrying out initial applications and projects, but for the time being at relatively low costs. Benefits and potentials of this new technology are recognized (decentralized, peer-to-peer, safety), but also barriers and risks considered.

Blockchain provides an opportunity for energy management companies to become first movers in this field. However, the risk is high, as the existing technology landscape is dominant and well-established, which means it is well-known to stakeholders and users alike and well embedded in the legal framework. The survey has shown that there is still a need for optimization from a technical point of view (e.g., computing and energy expenditure) as well as a great deal of legal and regulatory uncertainty leading to reserve among decision-makers towards blockchain. At present, due to the activities at rather low costs, it looks as though the energy industry is dealing with the topic of blockchain but still waiting to see how the technology develops. This provides the opportunity to keep up to date and explore branch-specific applications, but also holds the risk to be unable to actively influence the development. Since the energy stakeholders are aware of the fact, that the blockchain technology could have a disruptive character for certain actors in energy industry, it would be advisable to pro-actively participate in the development of applications and standards as well as regulatory framework conditions [9].

The project *SonnWende+* and the innovation lab *Energy Innovation Cluster Südburgenland* research such issues and offer a platform for knowledge exchange and further projects in this field. In the next years use cases will be implemented and tested in a co-creative environment, which will deliver insights in the acceptance, user-friendliness, and applicability of blockchain applications in different fields of energy management.

Acknowledgements

This work has been performed within SonnWende+ (project ID 861621) within the Austrian TRD program "Stadt der Zukunft".[9]

Das Projekt „SonnWende+" wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Programms „Stadt der Zukunft" durchgeführt

[9] Stadt der Zukunft ist ein Forschungs- und Technologieprogramm des Bundesministeriums für Verkehr, Innovation und Technologie. Es wird im Auftrag des BMVIT von der Österreichischen Forschungsförderungsgesellschaft gemeinsam mit der Austria Wirtschaftsservice Gesellschaft mbH und der Österreichischen Gesellschaft für Umwelt und Technik ÖGUT abgewickelt.

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Dipl.-Ing. Dr.nat.techn. Tanja Tötzer studied Landscape Architecture and Landscape Planning at the University of Natural Resources and Life Sciences, Vienna (BOKU) and is scientist at the AIT Austrian Institute of Technology GmbH since 1998, where she has worked in the fields of regional studies, environmental planning, innovation research and since 2013 in the Unit Sustainable Buildings and Cities in the Centre for Energy. She has essential experiences in supporting cities and regions in dealing with energy transition in several inter- and transdisciplinary projects. Since 2016, she has been lecturer at the TU Wien on the topics climate change, resilience and urban living labs.

Real-live energy use cases utilizing blockchain infrastructure

Thomas Zeinzinger, lab10 collective eG, thomas.zeinzinger@lab10.coop

Abstract – Within the research project SonnWende+ we came up with five possible block-chain use cases that would maximize self-consumption and foster local energy systems. These use cases are very different in their nature and consequently they cannot be handled via a single purpose blockchain like Bitcoin and need a free programmable infrastructure like Ethereum is offering. The current major limitation of open and permissionless blockchain systems like Ethereum is scalability and the unpredictability of transaction cost. Therefore, we are involving the latest developments in the blockchain space and present the public, permis-sioned ARTIS blockchain, which will be a sufficiently scalable blockchain system to handle the expected load and provide the needed data security and data protection in connection with the GDPR by involving decentralized storage and sensitive key handling in combination with good usability.

1. Introduction to Blockchain

Blockchain has been suggested to solve many problems and disrupt hundreds, if not thousands of businesses [1]. But after the recent hype has now cooled off a bit, people start to realize that it might take a little more time to get all the business relevant infrastructure and software in place.

Before someone is considering to use a blockchain system it is advisable to make a self-check if it adds additional value to the process or if a private or distributed database more suitable. In *Figure 1* one of many possible evaluations is given, highlighting the important aspect of trust or the lack of it.

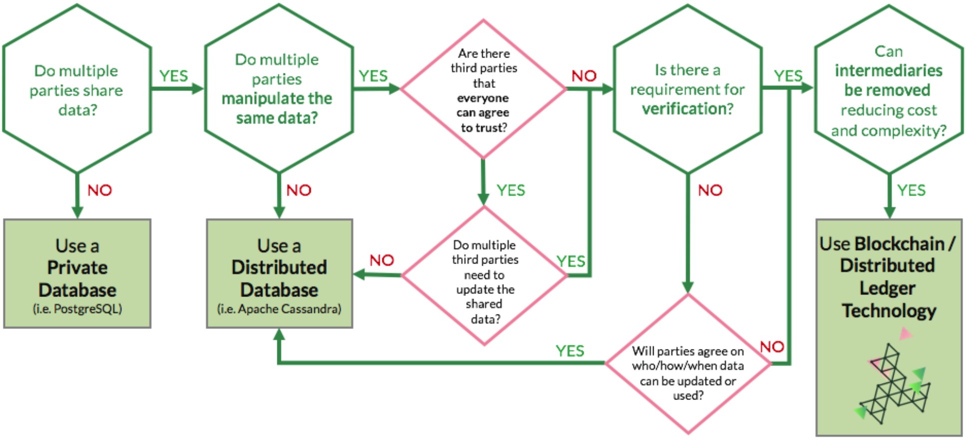

Figure 3. Decision process - When to use a blockchain?

1.1 History of blockchains

In 2008, at the height of the financial crisis, the Bitcoin whitepaper [2] was posted by an anonymous person or group called Satoshi Nakamoto. This system, which was launched early 2009 had a sole purpose - allowing the transfer of value without a central authority administrating it. Few insiders took the system serious and it took until 2010, when the first value was assigned to Bitcoin. In 2013, a 19-year old Canadian-Russian by the name Vitalik Buterin published the Ethereum whitepaper [3] and when the system finally launched in 2015, it captured massive interest as the first decentralized "World Computer" [4]. Decentralized Applications ("DApps") and Decentralized Organizations ("DAOs") where envisioned. But, so far Ethereum was mainly used for Initial Coin Offerings ("ICO"), because of the simplicity to generate a token which could be sold to investors mainly in exchange for other cryptocurrencies. Ethereum has also started a race to build the next "best" blockchain system with Cardano and EOS being the most vocative competitors.

The high interesting in blockchain has also caused a major push to develop enterprise specific solutions in the form of Hyperledger, Corda, Quorum and many more. Also, many consortia, like the Ethereum Enterprise Foundation where founded to solve enterprise requirements. Enterprise blockchains in comparison with Bitcoin or Ethereum is like comparing Intranets with the Internet. Therefore, they should not be seen as competing efforts – they rather complete each other.

1.2 Blockchain Categorization

Blockchains can be used in many ways and with more and less transparency. In *Table 1* the most simplistic way of categorizing blockchain system is given, but the interested reader will find many nuances in every category.

		Transaction Confirmation	
		Permissionless	Permissioned
Access	Public	Everybody can read and write (e.g. Bitcoin, Ethereum, ...)	Everybody can read and only allowed members can write (e.g. Sovrin, ...)
	Private	Only allowed members can read and everybody can write (no use case)	Only allowed members can read and write (e.g. Hyperledger, Corda, ...)

Table 1: Categorization of blockchain systems regarding 'Access' and 'Transaction Confirmation'.

Another differentiator is a possible Turing completeness of its scripting or programming language for smart contracts and whether these programs are done on-chain of off-chain.

2. Challenges

Even if a use case has proven 'worthy' for blockchain (see *Figure 1*), one must take into consideration many other limitations of blockchain systems. The limitation of scalability (more below) became fully visible when a game called "Cryptokitties" launched on Ethereum. People could breed and trade unique cute little kittens and caused a massive congestion on the Ethereum blockchain - see *Figure 2*.

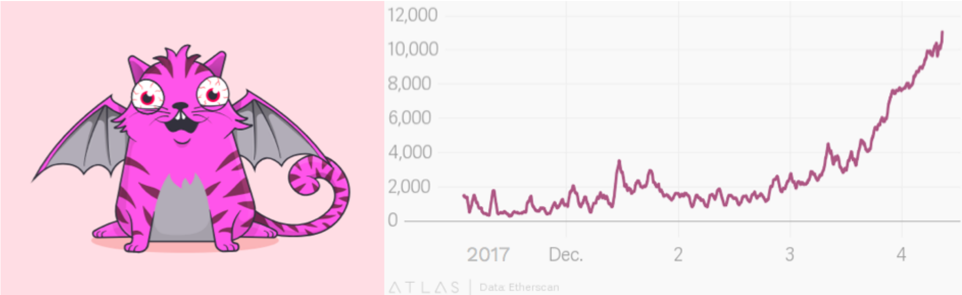

Figure 2: Pending Ethereum transactions after Cryptokitties release in Nov 2017.

2.1 Blockchain specific challenges

Scalability

Today's blockchain systems don't scale and consequently massive effort is put into new developments around on-chain, off-chain and smart contract scaling proposals, which are partially outlined in *Table 2*. They are applicable for various use cases and it will be up to the developers, to choose the most suitable option for their project.

Scaling:	**On-Chain Transactions**	**Off-Chain Transactions**	**Computations (Smart Contracts)**
Bitcoin	SegWit	Lightning Network	Scriptless Scripts [5]
Ethereum	Sharding, Proof-of-Stake, State Channels, Streem	Raiden, Plasma, OpenST	Truebit
Zilliqa	Sharding, Proof-of-Stake		
EOS	Proof-of-Stake	Sidechains	Asynchronous Smart Contracts

Table 2: Overview on blockchain scaling solutions in various projects.

The typical metric used to describe the throughput in blockchains is transactions per second and when one intends to interact with blockchain systems, it must be considered that typically 3 - 2000 tx/s can be processed and this capacity is shared with everyone in the world.

Cost of Operation

The major problem with non-scaling blockchain designs is, that as soon as the blockchain is becoming full (only Bitcoin and Ethereum have reached that level) the transaction fees are climbing due to market forces. At the time of writing the average Bitcoin and Ethereum transaction fee was about 0.5 and 0.2 USD respectively, which is already well beyond the acceptance level of most use cases. Further details about the transaction-cost history can be found at [6].

2.2 Use case dependent challenges

GDPR (General Data Protection Regulation)

The GDPR is worldwide the strongest data protection regulation and penalties for non-compliance can be of €20 million, or four percent of worldwide turnover. Due to the 'history preserving nature' of blockchains special care must be taken regarding "Personal data" (specified in Article 17 of the GDPR) and it does not matter if the blockchain system is public or private.

Data storage

Blockchains are very expensive for data storage, e.g. 1kByte of data storage in Ethereum could cost from 1.8 to 60 USD in 2018. Buterin explained during a recent conference [7] that currently the cost of storage in Ethereum are about 1M times higher than on an AWS cloud storage system.
Several projects working on decentralized and incentivized storage protocols. While the Ethereum specific SWARM protocol is still in its infancy, the IPFS ("Interplanetary File System") has already gained broad support and has collected 257M USD during their Filecoin ICO in 2017.
Futhermore, leaving data on IPFS and only linking it to a blockchain system simplifies GDPR compliance.

Usability

The first five years in blockchain happened almost completely on the computer console level and was therefore inaccessible to average users. Since 2013 the usability is constantly being improved and during the last two years' major progress was made to develop software libraries and user interfaces needed for mass adoption.
The Ethereum community is heavily pushing towards a completely serverless and decentralized web – calling it "Web3". This also leads to the development of many needed tools simplifying the interaction with an underlying blockchain protocol, allowing further abstractions to hide the complexities from the end user in the upcoming years.

Identity

When Bitcoin made blockchains popular, it was a feature to only use pseudonyms - in the form of addresses - as "identity". It provides a certain form of anonymity, but this is not feasible for most business transactions.
Consequently, many companies have worked on additional identity layers for blockchain systems with a lately increasing drive towards Self-Sovereign Identity ("SSI"). Users can stay in control of their identity (identities) and improve privacy during electronic interactions by using 'Zero-Knowledge Proofs' and 'Verifiable Claims'.

3. Energy and SonnWende+ use cases

The Energy sector is one of the most active blockchain domains and use cases cover many fields – e.g. Peer-2-Peer trade, EV charging & billing, global PV crowdfunding, energy trading platforms, 'all-inclusive' application platforms, carbon credit systems, loyalty schemes or fast utility change platforms.
Within the SonnWende+ projects' scope we have identified five use cases where blockchain can provide solutions. Three of them will be outlined here with further details while use case 4: "Peer-to-peer energy trading" and use case 5: "Optimization in energy communities" are described in [8].

3.1 Use Case 1: Transparency for crowd-invest

House-owners provide their roof surface area, investors provide money for purchasing and installation of new facilities. These costs are rediscounted by the energy savings due to self-consumption or an energy surplus. After complete clearance (including interest), the facility will pass into the ownership of the house-owner.
Problem statement: Insufficient funding by investors for private PV installations
Cause: only regional reach for investments, high administrative burden and problems with trust.
Blockchain can serve as a highly transparent trust layer, can reduce administrative burden and can even be used to move money on a global scale without involving expensive legacy banking infrastructure.

General Challenges: Smart Meter Data Access; Decentralized Storage Layer; GDPR; KYC / AML Regulation; Volatility of Cryptocurrencies; Available Payment Processors; Hardware Security; Usability
Project Focus: Document the capital flow for house-owners and investors on a public blockchain system and make it accessible for them.

3.2 Use Case 2: Energy-ledger

This use case represents a loyalty scheme (e.g. like Miles-and-More) which rewards energy-efficient behavior (e.g., optimization of self-consumption, installation of heat-pumps). The collected points can be used to utilize benefits at other participating parties (e.g., lower energy costs at a e-car charging station).

Problem statement: Regular loyalty schemes contain a high contractual cost burden, inflexibility, walled-garden like structures and high IT infrastructure burden.

Cause: Centralized structure with extensive legal documents.

Blockchain can serve as a secure way to transfer points and use them for discounts within the partner network. In combination with oracles[10] the generation and current 'value' of points can be used for instant feedback and gratification of energy efficient behavior. Furthermore, people could receive additional status points within their energy community.

General Challenges: Smart Meter Data Access; Decentralized Storage Layer; External data access (Oracles); GDPR; Combination with other payment methods; Hardware Security; Usability

Project Focus: Connect a public blockchain system to a centralized loyalty point system and integrate at least one use case.

3.3 Use Case 3: Contactless automatic charging

Automated and contactless e-car charging will play a major role in the futures e-mobility. Whenever a car stops at the infrastructure (integrated in the floor), an automatic charging process will be started until the battery is completely loaded (or until it reaches the user-defined level) or the car will start moving again.

Problem statement: Current EV charging is neither simple nor convenient for the user

Cause: Few e-cars have promoted a 'membership only' charging infrastructure.

Blockchain can massively simplify this system – no registration, only payment of what is consumed. This will basically allow everyone to provide a charging facility and get payed, while there is basically no lower limit for the charged amount as it is customary with credit card systems.

General Challenges: Usability; GDPR; Car Integration; Availability & Acceptance of Stablecoins[11], Hardware Security; Usability

Project Focus: Demonstration of a working prototype which is developed out of a co-creation process together with e-car users.

[10] Oracles provide a connection to external data sources, which are needed for smart contracts within a blockchain system.

[11] Stablecoins are cryptoassets with a stable (e.g. 1:1) exchange rate to fiat-currencies like Euro or Dollar.

The SonnWende+ project will end in Autumn / Winter 2019 and the Innovation Lab act4.energy will be the location to demonstrate and present the results from described use cases.

4. Blockchain Decision Matrix

Among the Top 20 blockchain systems on Coinmarketcap.com, five offer smart contract development possibilities.

	Ethereum	EOS	Cardano	NEO	NEM
Coinmarketcap.com Position	#2	#5	#9	#14	#18
Main Core Development	**EU** / USA	USA	China	China	Japan
Native Cryptocurrency	Ether	EOS	ADA	NEO	XEM
SSI Identity System	Alpha	No	No	No	No
Name Service	Beta	No	No	No	Yes
Fully Programmable (Smart Contracts)	Yes	Yes	**No**	Yes	**No**
Programming language (Smart Contracts)	Solidity, **WASM**	C++	-	C++, Java, …	-
Low Transaction Cost	**No**	Yes	Yes	Yes	Yes
Web Libraries (Blockchain Connection)	**Yes**	**No**	No	**Yes**	Yes
Stable Blockchain Operation	Yes	Security Issues	Yes	Yes	Yes
Fully Open-Source	Yes	Yes	Yes	Yes	**No**
Energy Efficient Operation	**Not Yet**	Yes	Yes	Yes	Yes
Decentralization (‘Mining’)	**High**	**Low**	Unknown	**Low**	High
Scalability Research	High	High	Unknown	High	No
	1.	**3.**	**-**	**2.**	**-**

We concluded that Ethereum offers the best option to implement SonnWende+ use cases. Most noteworthy reasons are:

- There is a very big developer community in Europe and many conferences and workshops are conducted with Ethereum ‘only’ topics.
- It offers already a rich development environment for applications and WebAssembly (WASM) will significantly improve the security of smart contracts.
- Ethereum will move from energy intense Proof-of-Work to energy saving Proof-of-Stake.

- The transaction cost problem can be easily mitigated through Sidechains connected with the Ethereum mainchain.

ARTIS will be the Ethereum code base blockchain system and MINVERVA the needed mobile application connecting to it in a secure and simple way.
ARTIS will use the Proof-of-Authority consensus, which allows high throughput and low latency. Connections to Ethereum will be done via a bridge and via Plasma [9].
MINVERVA will handle self-sovereign identity, wallet and an API for simply connection between mobile applications.

Acknowledgment

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Das Projekt „Sonnwende+“ wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Programms „Stadt der Zukunft“ durchgeführt

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Blockchain – Regulieren oder Nichtregulieren, das ist hier die Frage!

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Abstract. Distributed Ledger Technologien (kurz: DLT) mit ihren prominentesten Vertretern, den Blockchains, beschäftigen nun schon eine ganze Weile die Energiebranche und schaffen es regelmäßig in die Schlagzeilen und Keynotes vieler Fachkonferenzen. Der Hype ist ungebrochen und die Anzahl von Startups in diesem Bereich steigt stetig, ebenso wie die darin investierten Mittel bereits arrivierter Marktteilnehmer.

Zur Erinnerung: Unter Blockchain versteht man die Technologie, die einer speziellen Form von sicherer, verteilter und dezentraler Datenhaltung und den dafür nötigen Datenaustauschen zugrunde liegt. Blockchains sind stetig wachsende Aufzeichnungen von rückwärts gekoppelten Datenbankeinträgen („Ketten von Datenblöcken“, eben den Blockchains), die auf einer Vielzahl von Computern in öffentlichen oder privaten Netzwerken fälschungssicher abgelegt und synchron gehalten werden.

Potentielle Anwendungen dieser Technologie in der Energiewirtschaft erstrecken sich von einem effizienteren Datenaustausch, über Abrechnungssysteme für E-Mobility, die Verwaltung von Herkunftsnachweisen, Vereinfachungen im regulatorischen Reporting bis hin zum sogenannten „Peer-to-Peer“ Handel dezentraler Erzeuger und Verbraucher.

Auch wenn die technische Weiterentwicklung im Bereich DLT zügig voranschreitet, so haben sich doch kaum Projekte in der Energiebranche über die Proof-of-Concept Phase hinausbewegt. Die Gründe dafür liegen möglicherweise an fehlenden Business Cases oder auch an rechtlichen und regulatorischen Unsicherheiten.

Gerade in diesem Umfeld ist es für eine Regulierungsbehörde wie der E-Control wichtig zu signalisieren, dass ein grundsätzliches Verständnis für solch neue Technologien vorhanden ist und die Bereitschaft besteht, diese soweit möglich im bestehenden Regulierungsrahmen zu interpretieren bzw. an einer Weiterentwicklung desselben zu arbeiten.

Als ersten Schritt hierzu hat E-Control einen Kurzbericht „Blockchain in der Energiewirtschaft“ veröffentlicht [1]. Darin nähert sich die Regulierungsbehörde dem Thema aus Sicht der Energiemarktregulierung an.

Wesentliche Erkenntnis der bisherigen Analysen ist, dass eine pauschale Beurteilung von Block-chain/DLT-Anwendungen durch die Vielfalt konkreter Implementierungen mit ihren unterschiedlichen technologischen und organisatorischen Eigenschaften erschwert wird. Aus

heutiger Sicht sind aber zumindest die nachfolgenden Prinzipien zu berücksichtigen: Technologieneutralität, Sektor- und Ländergrenzen-übergreifende Harmonisierung und Standardisierung, die Einhaltung regulatorischer Grundziele (Versorgungssicherheit, Wirtschaftlichkeit, Energieeffizienz, Leistbarkeit, Nachhaltigkeit), ein klarer und stabiler Regulierungsrahmen sowie die Geschäftsmodell-Neutralität.

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DI Dr. Clemens Wagner-Bruschek, ERP. Das Berufsleben von Clemens Wagner-Bruschek ist geprägt von seiner Neugier und Freude daran, komplexe Herausforderungen zu verstehen und ihnen mit adäquaten Mitteln zu begegnen. War es zunächst in der mathematischen Forschung, so setzte er seine analytischen Fähigkeiten und strategische Denkweise bald in der Beratung führender Energie- und Finanzkonzerne ein. Nach lehrreichen Jahren in der Unternehmensberatung führte ihn sein Weg zum österreichischen Regulator E-Control, wo er als stellvertretender Abteilungsleiter der volkswirtschaftlichen Abteilung tätig ist. Er ist Teil des Marktüberwachungsteams unter REMIT, beschäftigt sich mit den Beziehungen zwischen Energie- und Finanzmarktregulierung und mit Aufgaben des Datenmanagements und der Datenanalyse. In all dieser Zeit hat er nie sein Interesse an neuen Technologien verloren und so war es nur eine Frage der Zeit, bis er einen Teil seiner Arbeit dem Verständnis und der Analyse von Digitalisierungsthemen wie Blockchain und deren Auswirkungen auf moderne Märkte widmete.

Applications of Blockchain in the Energy Distribution System

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Abstract – Blockchain applications are gaining widespread interest in the energy domain due to their decentralized and audit-proof nature. In the distribution system and in the user domain, blockchain-based applications aim at fostering a tighter integration of customers. In the course of establishing a smart grid, where energy is to a great extent produced from decentralized and privately owned power plants, customers actively participate in both, the creation and the consumption of energy. In this work, (i) the objectives and insights from the FFG ProChain project are discussed; and (ii) the prototypical implementation of a blockchain for a selected use case are presented. The project analyzes the potential and the challenges of blockchain technology in the distribution system, as well as the degree of customer participation. For the selected use case of sharing energy from privately owned photo voltaic power plants, a prototypical blockchain is implemented and the challenges and insights gained from such an implementation are shown.

1. Introduction

We are in the transition from a traditional energy grid, where energy production follows customer demand to a *smart grid*, where customer demand follows energy production. This requires a high level of customer acceptance and customer participation. Customer change their role from being purely a consumer to being a prosumer. In a smart grid, energy is not only produced at large-scale centralized power plants, but to a great extent at small, decentralized and often privately owned power plants that generate power from renewable energy resources. This poses new challenges, not only to the electricity grid itself, but also to information and communication technologies.

Blockchain technology is often seen as one of the key technologies for the smart grid and many applications for blockchain in the field of energy distribution and trading have already been proposed, e.g., [1]–[3]. Blockchain technology allows to store data decentralized and audit-proof and maintains a common state without the need of a trusted third party. The concept of blockchain has originally been introduced in 2008 by Nakamoto [4]. Since then, the technology significantly evolved and many new blockchains have been proposed that are for general purposes, e.g., Ethereum [5], or that are tailored to specific needs such as privacy, e.g, HAWK [6].

While blockchain technology comes with many features that seem beneficial at first, a detailed analysis of specific use cases often shows some drawbacks. Blockchains allow to maintain a common state among a number of (potentially) unknown and untrusted parties without the need of a central authority. However, many state of the art blockchains either have high-computational costs, high latency and limited throughput or do not provide advanced privacy mechanisms [7], [8].

In the FFG ProChain project, a consortium consisting of two major Austrian utility companies, Salzburg AG and Verbund AG, a distribution system operator, Salzburg Netz GmbH, a blockchain enterprise, GSy GmbH, and the research institutions AIT Center for Technology Experience and the Center for Secure Energy Informatics from Salzburg University of Applied Sciences, are investigating the applicability and future role of blockchain applications in the distribution system. The key aspects investigated in this work include,

(i) the applicability of various blockchain technologies and consensus mechanisms for selected use cases; and

(ii) the role of customer integration and participation in blockchain applications in the user domain.

In this paper, the objectives and first insights from the project are discussed. Furthermore, a prototypical blockchain implementation for the selected use case of sharing energy from privately owned photo voltaic power plants serves as the basis for presenting the challenges and insights gained from such an implementation from scratch.

The rest of this paper is structured as follows: Section 2 introduces blockchain technology and related work in the field of existing implementations. Section 3 introduces the ProChain project, the objectives and investigated use cases as well as first results. Section 4 shows the insights from the prototypical blockchain implementation and Section 5 summarizes this paper and gives an outlook to future work.

2. Blockchain Technology

Blockchain technology can be described as a trustless and fully decentralized peer-to-peer data storage that is spread over all participants that are often referred to as *nodes*.

The blockchain is designed to hold immutable information once data is committed to the chain and it is therefore a decentralized, distributed and immutable database in which data is logically structured as a sequence of smaller chunks (blocks). Each block $B_{i>0}$ is immutably connected to a single preceding block B_{i-1} through a cryptographic hash function $H(B_{i-1})$. Changes to B_{i-1} would yield an invalid hash in B_i and all following blocks. This ensure audit-proneness with respect to future changes. The very first block B_0 is called the *genesis block* and is the only block without a predecessor. In order to assure the integrity of a block and the data contained in it, respectively, the block is usually digitally signed.

For some applications, it is more useful to view a blockchain as a state machine [5]. Each block contains a new state with the very last block representing the current state. Given the list of blocks and the data in this block, there is a unique and immutable order of transitions that lead to the current state.

The main features of blockchain technology can be summarized as follows:

(i) Decentralization: Instead of relying on a single trusted entity, trust is spread across multiple or all participants, depending on the agreed-upon consensus algorithm [9]. This does not only mean that multiple copies of a data item are stored on all nodes, but also that the integrity of the data is governed by many decentralized parties.

(ii) Immutability: Once data is committed to the blockchain and a sufficient number of participants have agreed on this state, the information is stored permanently and immutably and thus audit-proof. Changing the information contained in a particular block would require to also change all the following blocks up to the last block, which is considered to be infeasible [4], [10].

(iii) Scalability: The block rate, comprised of the throughput and propagation time of information, depends on the consensus algorithm and the number of participants. This can be a limiting factor for applications that require high throughput [9]. Since all nodes hold a copy of the blockchain, scalability issues also arise in terms of the total amount of data that can be stored. Furthermore, in order to check the integrity of the blockchain, a new node needs to download a copy and validate the integrity of the entire chain.

(iv) Limited Privacy: All data in the blockchain is publicly visible to all participants. Private or permissioned blockchains limit the range of disclosure. However, they do not cryptographically protect the data. In order to achieve privacy, additional layers, such as zero-knowledge proofs [11] or a commitment scheme are required [12].

A blockchain can be generalized to store arbitrary data. In its simplest form, a block B_i consists of the hash of the previous block, a payload (arbitrary data to be stored in the block), and a digital signature over the block data signed with the private key of the block creator. In public blockchains, all participants can create and append new blocks. Once a new block is created and successfully linked to the chain, it is broadcasted to the network.
If other participants receive such a new block and consider it to be valid (i.e., by verifying the signature, checking the hash, and checking the validity of the payload), they extend their local copy of the chain with the newly created block and eventually broadcast the block to other participants. If a block is invalid, it is discarded and does not become part of the chain.
Consenus, i.e., a global agreement on which block and which branch of the chain is valid, can be achieved through different mechanisms. Most commonly, proof-of-work, proof-of-stake or proof-of-authority are used.
Despite the advantages of decentralization, trust-lessness and immutability, there are two major issues with current blockchain technology – scalability and power consumption [9]. Scalability refers to the time needed for propagating, processing and validating transactions. The higher the number of nodes is, the more limiting network bandwidth, overall storage space and power consumption become.
The current power consumption (as of May 2018) of the Bitcoin network is approximately 70 TWh per year[13]. This is mainly caused by the approximately 35 exahashes per second ($3.5 \cdot 10^{19}$ H/s) which need to be computed for the proof-of-work consensus algorithm. Thus, for energy-sensitive use cases, using a blockchain such as Bitcoin in its current state is not a sustainable approach.

3. ProChain Project

In the FFG project ProChain, a consortium consisting of participants from the fields of energy production, energy distribution, industry and academia, are currently investigating the role of blockchain technology in the distribution system. While blockchain technology poses many advantages and is seen as a key technology for the smart grid, there are also limitations and drawbacks that need to be carefully considered when proposing and developing blockchain applications, especially for the operation in critical infrastructure such as the energy grid.

In this project, the applicability of various blockchain technologies and consensus mechanisms for selected use cases are investigated, and the role of customer integration and participation in blockchain applications in the user domain is evaluated. The use cases selected for this work include,

[13] https://digiconomist.net/bitcoin-energy-consumption

(i) demand response management, i.e., the applicability of blockchain technology to increase automation and efficiency of load curtailment;
(ii) electric vehicle charging, i.e., the use of blockchain technology to operate a decentralized charging infrastructure with a heterogeneous set of participants and roles; and
(iii) local energy trading, i.e., the role of blockchain technology in implementing new legislation that allows customers to transfer energy produced from small solar power plants within residential communities.

These use cases are evaluated with respect to the overall need for and the type of the blockchain (see [13]), the market potential from the perspective of energy providers and grid operators, and the degree of customer integration and participation with respect to privacy (discussed in, e.g., [3], [14]). An analysis from Salzburg AG, Salzburg Netz GmbH and Verbund AG has shown the relevance of this use case (iii), the local energy trading, due to new legislation to enable energy transfers between parties of a shared photovoltaic power plant that has been introduced in Austria in 2017 [15].

In particular, § 16a ElWOG 2010 [16] establishes the legislative basis to allow customers to agree on a distribution key for the share of energy generated by a shared solar power plant in a multi-party residential household. This share can be changed at an interval of 15-minutes. For multi-party households with shared solar energy plants, this allows to transfer energy of one party to another, instead of feeding excess energy into the public grid. In this use case a number of participants have to agree on a common state that changes over time. The participants are not known to each other (but they are all known to the distribution grid operator) and do not need to trust each other. Malicious customers may also attempt to double-spend their portion of energy. Due to the number of stakeholders involved, is appointing a single trusted third party infeasible.

Given this constraints and the requirement for a – comparably – low throughput due to the 15 minutes interval, blockchain technology is a promising technology for the implementation of this use case.

According to the evaluation process described in [13], a private permissioned blockchain is chosen for the underlying permission model. In a private permissioned blockchain only a set of known participants can read and write data from and to the blockchain. In this use case, the permissions can be managed by the local distribution system operator, which also installs and maintains the meters and handles the billing process and thus is the appropriate entity to control access to the blockchain. Note, however, that the distribution system operator is not involved in the transfer of shares. This is handled completely decentralized and fully based on the blockchain.

Further insights from the project include the need for hybrid blockchains where the consensus algorithm is uncoupled from the underlying blockchain. Such an approach is already presented in [17] and proposes to solve many of the scalability issues current implementations face. For time critical and data intensive applications in the energy domain, high throughput and low latency is an inevitable feature. The need for privacy-enhancing technologies that are built in blockchain implementations has also evolved since the original proposal of the technology in 2008. Today, blockchains are proposed for storing and transmitting sensitive and privacy critical data, such as energy consumption profiles [18]. In the next section the challenges for and insights from implementing this blockchain from scratch are presented. For achieving a high degree of customer acceptance and customer participation in novel blockchain-based application, the privacy and security features need to be carefully investigated and evaluated from a user perspective. So far, only a few attempts were made to evaluate the user acceptance of blockchain applications. For example, in [19], a typology of Blockchain use cases for Human-Computer Interaction is provided, and in [20] it is shown, that blockchain concepts might be too abstract for the target group and that transaction in the network are perceived as too risky and cannot be revoked. At the moment, only guidelines – which are not empirically evaluated – exist how to design user interfaces in blockchain applications, e.g., which kind of information should be displayed [21]. In the project ProChain we determine the requirements for blockchain applications in the context of energy from a user-centered perspective. In order to achieve this, we developed a lab-based investigation method where representative users are confronted with blockchain application prototypes and are inquired about relevant user acceptance factors. In the further course of the project, the resulting user experience model (see [22] for a detailed introduction of technology acceptance modelling) will be validated in a larger online study.

4. Implementing a Blockchain

For the use case of trading shares of energy within a multi-party household, a blockchain is implemented from scratch with the objective of (i) creating a prototypical implementation for this specific use case; (ii) learning the challenges of and get insights into blockchain technology and development; and (iii) using the implementation as the basis for further evaluation of customer participation and interaction with blockchain technology.

The implementation consists of three main components and an overview is shown in Figure 1. Each customer possesses an app that is connected to a node (for sending new transactions and receiving confirmations) and to the clearing server (for billing). New transactions (denoted as Tx) reside in a pool of unconfirmed transactions until they are mined by a node and appended to the blockchain. The clearing server retrieves data from the blockchain and sends billing information to the customers' smartphone apps.

The smartphone app acts as the interface for the user and allows to visually move shares of energy to neighbors. This triggers a new transaction that is sent to a blockhain node and stored in the unconfirmed transaction pool. Each customer also possesses such a node that implements the consensus algorithm to check whether a new transaction is valid or not. A transaction is valid if and only if a customer transfers a portion to a neighbor that (i) belongs to the customer; and (ii) has not been transferred before. A number of valid transactions is then mined into a new block and sent to all other nodes in the network. Additionally, the smartphone app receives incoming portions from the corresponding customer node.

A clearing server acts as an entry point for the distribution system operator and allows to retrieve the final values for each timeslot for billing purposes. Note that transactions do not consist of actual kWh values, but only of percentages of energy produced from the photovoltaic power plant. The actual values in kWh and monetary units are then calculated by the distribution system operator off-chain.

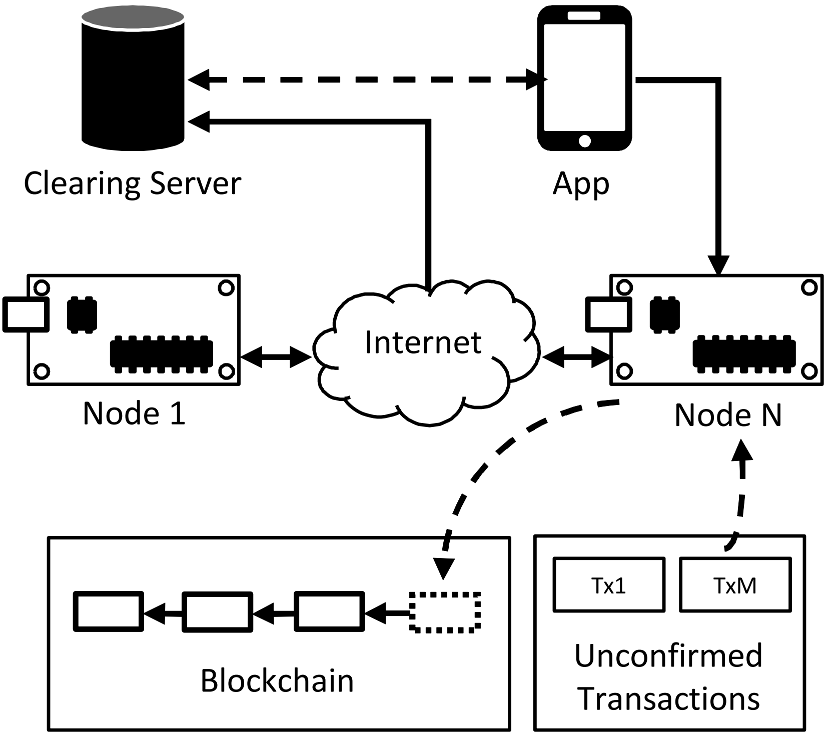

Figure 1. Overview of the components for the prototypical implementation. Customers can send and receive shares via an app. A node is used as the entry point to the blockchain for sending and receiving transactions. A clearing server reads the final values from the blockchain that are used for billing.

In the course of implementing the blockchain from scratch, the following insights were gained:

Idle Chains Are a Security Liability. If the transaction frequency is low, e.g., in this use case during night hours, no new blocks are created and in such an idle chain an attacker can pre-mine a large number of blocks and thus the longest branch of the chain, which would allow the attacker to deliberately exclude certain transactions from the chain. Our proposed solution is to allow the creation of empty blocks.

Better Performance Means Less Security. When determining the block rate, i.e., the difficulty of the puzzle in case of a proof-of-work algorithm, the balance between performance and security has to be carefully chosen, especially if there is only a small number of participating nodes. If the complexity for mining is low, the block rate increases, but makes it easier for powerful adversaries to attack the chain.

Resynchronization Is Hard. Eventually nodes get out of synchronization due to network failures or by later joining the network. This circumstance has to be detected by the node and a synchronization mechanism is needed that updates the node to the common state, i.e., the state the majority of the nodes in the network has. In the prototypical implementation a node can detect failures in synchronization if the delta between the blocknumber of incoming blocks and already processed blocks bcomes to large. The node can then request missing blocks from the sender of the new block.

The prototypical implementation is currently tested in the field and customer acceptance and customer participation is evaluated. First results are expected in early 2019.

5. Conclusion

In this paper applications of blockchain in the distribution system were presented within the scope of the FFG ProChain project and a prototypical implementation of a blockchain. The objectives and insights from the project with a consortium from both, industry and academia were discussed. The applicability of blockchain technology for three use cases, demand response, electric vehicle charging, and local energy trading are investigated. First results from the local energy trading use case that is based on new legislative requirements have shown the principal applicability of a blockchain-based solutions. Customers can transfer energy created from privately owned photovoltaic power plants within multi-party households. The proposed approach uses a private permissioned blockchain and handles the transfer of energy shares completely decentralized. A prototypical implementation of the blockchain from scratch serves as the basis for evaluating customer acceptance and customer participation. Furthermore, the challenges and insights from such an implementation were presented.

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Symposium Tag 2

Diskussion laufender Forschungsprojekte „beyond Blockchain"

Flex+ – der Aggregator der Zukunft

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Kurzfassung

Die Integration von Prosumern in Energiemärkte wird sowohl auf europäischer Ebene, wie beispielsweise im sogenannten Winterpaket, aber auch auf nationaler Ebene forciert, um die Prosumer aktiv ins Marktgeschehen einzubinden und mit Hilfe ihrer Flexibilität fluktuierende erneuerbare Energien zu integrieren. Aus technischer Sicht eignen sich dazu vor allem automatisch ansteuerbare Prosumer-Komponenten wie Wärmepumpen, Elektroboiler, PV-Speichersysteme und die E-Mobilität. Befragungen in den Projekten MBS+ und EcoGrid EU haben gezeigt, dass von Seiten der Prosumer durchaus großes Interesse besteht, ihre Flexibilität extern zur Verfügung zu stellen, um damit einen Beitrag zu einer raschen und für die Gesellschaft leistbaren Energiewende zu leisten. Anders als in Österreich gibt es in Deutschland und der Schweiz bereits vereinzelt bestehende Geschäftsmodelle im Bereich privater Flexibilitäts-Vermarktung. Aufgrund der unterschiedlichen rechtlichen, regulatorischen sowie wirtschaftlichen Gegebenheiten sind diese jedoch nicht direkt auf Österreich übertragbar. Untersuchungen in den genannten Forschungsprojekten zeigen darüber hinaus, dass die Bereitschaft der Prosumer zur Mitwirkung sehr stark von bestimmten Faktoren wie z. B. der Berücksichtigung ihrer Eigeninteressen abhängt – ein Aspekt der bei bestehenden Geschäftsmodellen auch in anderen Ländern nicht oder nur unzureichend berücksichtigt wird. Im Vergleich dazu spielen finanzielle Interessen eine weniger wichtige Rolle. Um das vorhandene Potenzial unter wirtschaftlichen Aspekten zu erschließen, müssen die Bedürfnisse der Prosumer daher entsprechend berücksichtigt werden.

Im Projekt werden skalierbare Optimierungsalgorithmen auf Aggregator- und Prosumer-Ebene entwickelt, die nicht nur die Interessen des Aggregators, sondern auch die Bedürfnisse/Eigeninteressen der Prosumer berücksichtigen und unter dieser Prämisse eine für alle Beteiligten optimale Märkte-übergreifende Nutzung und Vermarktung der vorhandenen Flexibilität in privaten Haushalten ermöglichen. Diese werden anschließend für ausgewählte Märkte, wie beispielsweise Spot-und Regelenergiemärkten sowie Minimierung der Ausgleichsenergie, im großflächigen Realbetrieb getestet und evaluiert. Während bestehende Geschäftsmodelle jeweils nur für eine einzelne Komponente/Technologie verfügbar sind, zielt das geplante Projekt darauf ab, die Flexibilität verschiedener Komponenten in einem Haushalt wie z.B. Wärmepumpen, Elektroboiler, Batteriespeicher und E-Mobilität zu nutzen und diese Märkte-übergreifend für verschiedene ausgewählte (System-)Dienstleistungen nutzbar zu machen. Als

Schnittstelle zum Markt wird eine Plattform (Flex+ Plattform) entwickelt, die die Koordination zwischen den Prosumern und den Lieferanten übernimmt und für Vermarktung, Planung und Vorhersage, Aggregation sowie den bedarfsgerechten Abruf der Prosumer-Flexibilitäten zuständig ist. Prosumer haben dabei über ein im Projekt gemeinsam mit den zukünftigen Nutzern entwickeltes User-Interface die Möglichkeit, ihre individuellen Eigeninteressen zu spezifizieren und damit die mögliche Flexibilitäts-Vermarktung zu beeinflussen. Da es keine bestehenden Lösungen für eine solche Plattform sowie für die zur Berücksichtigung der Eigeninteressen erforderliche dynamische Interaktion zwischen Flex+ Plattform und Prosumer gibt, werden im Projekt entsprechende Konzepte entwickelt, umgesetzt und getestet. Weitere Ziele im Projekt sind die Entwicklung geeigneter Verfahren zur Prognose der nutzbaren Flexibilität privater Haushalte sowie die Berücksichtigung möglicher Auswirkungen auf das Stromnetz (in enger Abstimmung mit dem bereits laufenden Leitprojekt LEAFS). Um eine hohe Akzeptanz der entwickelten Lösungen sicher zu stellen, werden Nutzer mittels Co-Creation über den gesamten Projektverlauf in das Projekt eingebunden.
Basierend auf den Ergebnissen des Realbetriebs werden Vergütungsmodelle und Tarife für Prosumer entwickelt und notwendige Prozesse bei Prosumern und Unternehmen entlang der gesamten Wertschöpfungskette implementiert.

Danksagung

Das Projekt „Flex+“ wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Programms „Energieforschungsprogramm“ durchgeführt

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VirtueGrid - Virtualisierung in digitalisierten Energiesystemen

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Florian Kintzler, Siemens

Kurzfassung

Zur Integration erneuerbarer Energien in das bestehende Stromnetz stellen Informations- und Kommunikationstechnologien (IKT) eine Schlüsseltechnologie dar. Neben den aktuellen Anwendungen Metering und Billing werden zukünftig auch Stromnetz-Monitoring, -Regelung, und dezentrales Energiemanagement eine große Rolle spielen. Unter den neuen Voraussetzungen (große Anzahl neuer Knoten, heterogene Systemelemente in unterschiedlich kritischen Bereichen) müssen die auch bisher geltenden Ziele Verfügbarkeit, Sicherheit, Resilienz und Effizienz der Kommunikationssysteme weiterhin erreicht werden. Eine reine Skalierung der heute für den Verteilernetzbetrieb eingesetzten IKT mit Ergänzung durch ein State-of-the-Art Sicherheitskonzept reicht dazu nicht aus. Die noch vorwiegend manuellen Verfahren für Maßnahmen wie Störungsmanagement, Konfiguration neuer vernetzter Komponenten oder Test neuer IT-Komponenten erweisen sich hier als höchst ineffizient.

Virtualisierungskonzepte aus dem IKT-Bereich, konkret Cloud- und Edge-Computing sowie dynamische virtuelle Local Area Networks oder Software-Defined Networking bieten potentielle Lösungen für praktische Kernfragen wie beispielsweise die Konfiguration neuer Protokoll-Stacks, Cross-Layer-Optimierungen zwischen Energie- und Kommunikationsnetzen, Integration von non-IP-Traffic, Legacy-Komponenten oder der zeitnahen Prüfung der Systemintegrität. Durch Virtualisierung liegen die Komponenten eins dezentralen Automationssystems scheinbar zentral beisammen und können an einer Stelle konfiguriert und betrieben werden. VirtueGrid untersucht, auf welche Weise und wie gut Virtualisierungstechnologien die wesentlichen zukünftigen Anwendungsfälle unterstützen können.

Im Kontext von drei Forschungsfragen werden neue Lösungskonzepte entwickelt:

1. Mit welchem Ansatz lässt sich der Konfigurationsaufwand bei der zuverlässigen und sicheren Integration zusätzlicher intelligenter Stromnetzkomponenten sowie Patch-Management mithilfe von Virtualisierung (scheinbar zentraler Konfiguration) minimieren?
2. Auf welche Weise lässt sich bei freier Verschiebung von Prozessen dezentraler Regelungssysteme im IKT-Fehlerfall bis hin zum IKT-Ausfall die Systemzuverlässigkeit erhöhen bzw. kann Graceful degradation auf Anwendungsebene realisiert werden?
3. Wie unterstützt Software-Defined Networking als ein Ansatz zur Netzwerk-Virtualisierung die Situationserkennung im IKT-Netz, d.h. die proaktive Erkennung von Überlast, Fehlern und Angriffen und wie kann eine schnelle Wiederherstellung der Telekommunikations-Konnektivität im Fehler- und Angriffsfall erfolgen?

Eine Evaluierung der entwickelten Konzepte findet dreistufig in Simulation, Labor und einer Feldumgebung im Bereich der Linz Strom, KELAG/KNG und IKB statt.

Danksagung

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Engineering and Validation Support for Smart Grids using Model-Based and Machine Learning Methods

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Abstract – The rollout of smart grid architectures and solutions has already started. New and intelligent methods are deployed to the distribution grids today. However, complexity is still increasing as focus is moving from a single system to a system of systems perspective. As a result, increasing engineering efforts and complexity lead to escalating costs. New and improved engineering and validation methods can help counteract this trend. This paper presents such an approach using model-based and machine learning methods. It supports the engineer during the implementation by minimizing tedious and error prone manual tasks as well as providing decision support. The proposed concept is expected to be able to reduce the amount of manual effort and in the end, lower the total engineering cost.

1. Introduction

The technology development and rollout of smart grid technologies is on the way. The vast deployment of renewables in recent years is leading to a needed change in terms of planning and operation of the distribution systems [1]. Information and Communication Technology (ICT), with sophisticated automation systems, are key enablers to handle these new challenges [2]. It can also be expected that the total complexity of these systems will increase even more in the future. Microgrids, regional energy, or hybrid grid approaches are only some examples of new technologies [3]. Another example is the concept of smart cities, where smart grids are only one component of a large sustainable system of systems [4]. Consequently, the electric energy system is moving towards a complex Cyber-Physical Energy System (CPES) [2].

However, new approaches and concepts are also followed by new challenges. The implementation of solutions for such CPES is associated with increasing complexity in design and development, also resulting in increased engineering costs. The traditional engineering methods used for power system automation were not intended to be used for applications of this scale and complexity [5], [6]. Hence, the provision of suitable automation architectures, corresponding tools, and methods holds huge optimization potential for the whole engineering process [7].

One methodology that can be used to reduce the engineering complexity is to start with a detailed use case and requirements engineering. Recent smart grid projects are also utilizing this approach for the development of different applications [8]. Currently, two of the most common methods for handling use cases and requirements are the IEC 62559 use case approach (also known as IntelliGrid) and the Smart Grid Architecture Model (SGAM). These methods complement each other, and the main aim is to provide clear and structured documentation of the use case and requirements.

A proper application of these use case methods results in a large amount of collected information. However, existing approaches are not based on formal, machine-readable representations of this information and they can thus not be processed in an automated fashion in the subsequent engineering phases (implementation, validation, and deployment). Instead, the engineer needs to manually "redefine" it, which is a very time-consuming and error-prone approach. Furthermore, the aforementioned approaches do not allow the reuse of other already existing input specifications that are typically provided as an input to the engineering process, such as e.g. IEC 61850 specifications or power system models. Consequently, current engineering approaches require a significant amount manual work that could be avoided in the design and implementation of smart grid solutions and applications.

This paper addresses these issues with a concept for an automated and model-based engineering and validation framework, which is currently being developed in the Austrian MESSE project. The remaining part of the paper is organized as follows: Section 2 provides a general overview of the overall engineering and validation support approach. How this method is being applied for the design and testing of two use cases is discussed in Section 3. This work is concluded with the main findings in Section 4.

2. Model-Based Support System for Engineering and Validation

This paper presents a concept for a model-based engineering and validation support system that covers the overall engineering process for smart grid applications—from use case design to validation, and finally deployment and commissioning. The approach is based on model-driven engineering methods and consists of four main parts: *(i)* specification and use case design, *(ii)* automated engineering, *(iii)* validation and deployment, and *(iv)* cognitive learning of user design experience [9]. The overall concept is depicted in Figure 1.

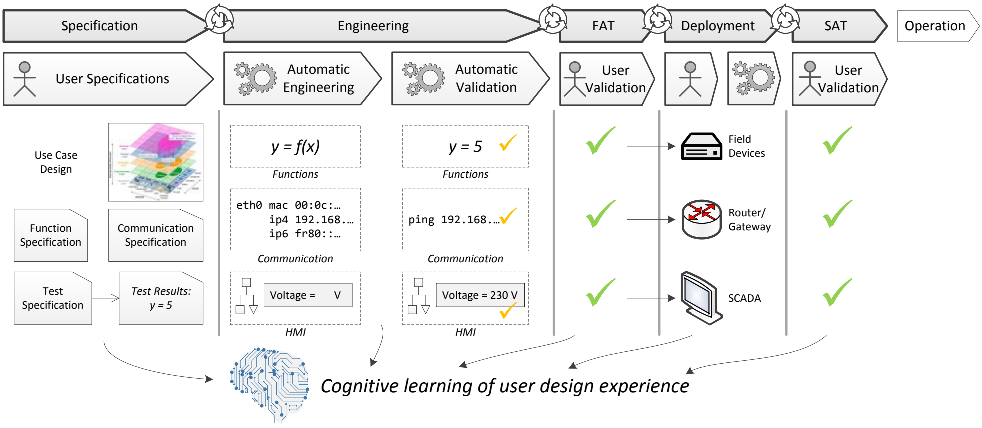

Figure 4. Concept of the model-driven approach for engineering and validation support

2.1 Formal Approach for Design and Specification of Use Cases and Applications

As mentioned in the introduction, the current state of practice provides limited support for formal and structured specifications of use cases for smart grids. Until recently, the need for detailed use case descriptions was not very high, due to a limited number of complex applications. However, with a more wide-spread use of advanced ICT-based automation systems this is changing.

The use case description methods defined in SGAM and IEC 62559 allow structured descriptions and visualizations of use cases, which can be used for informal exchanges of use case descriptions between different business units and between different operators. However, to take full advantage of the high amount of use case information a complete machine-readable and formal description format is needed. Similar approaches are currently being proposed, such as [10].

The methodology must support several different specifications with various levels of detail. On the one hand, high-level use case descriptions, like SGAM, must be possible. On the other hand, more detailed specifications of functionality, communication, as well as information models must be enabled. The methodology must also allow extensive specification of validation scenarios and expected test results. Current state-of-the art in automatic software testing as well as Design of Experiments (DOE) will be used as a basis [11]. However, since not only software is involved in the development of smart grid applications pure software testing will not be enough.

The final specification methodology should also be capable of being integrated into different software tools. The first phase in Figure 1 shows the idea of the *specification* process for this work. From a user perspective this is the phase of the engineering process that contains the most manual work. Therefore, it is important that the specification methodology guides the user. This is also vital to ensure the quality of the automatic generation phase. The automatic generation uses the specification as input, which means the quality of the automatic generation will only be as good as the quality of the specifications. During the specification phase several descriptions for different domains (e.g., functionality, communication) will be available. These must be combined into a semantic-based holistic model.

2.2 Automatic Generation of Target Configurations and Functions

Based on the specifications phase, different types of configurations can be generated. In the MESSE project the main focus is on executable code for field devices, communication configurations as well as Human-Machine Interface (HMI) configurations. The executable code is a platform-specific source code, which can be executed on a certain controller platform or a simulation platform. Generated communication configurations are used to configure the ICT setup, which includes information sent between actors as well as low-level configuration of the network. HMI configurations are used to define the layout of visualizations, but also to configure how user actions should be interpreted and executed.

By using model-based approaches from software engineering, a concept is provided for the automatic generation. This has multiple advantages. Automatic model transformations make it possible to keep the information unambiguous (i.e., changes in one input specification are also reflected in the others). Through model transformations it is also possible to automatically generate executable code or simulation models based on the semantic-based model. Another possibility is to use template-based approaches, where the user can define a generic layout of the HMI.

2.3 Automatic Validation and Testing

Automated testing for software development is a topic that already exists since several years. However, similar approaches for smart grid systems are currently missing. Nevertheless, validation and testing have always played an important role also for electric energy systems. In fact, before components can be connected to the grid, validation and audits are always needed. Until now these tests have focused mainly on the single components. It is only recently that integrated approaches for the analysis of smart grid system aspects are emerging, where also information, communication and automation/control topics are addressed [11].

In MESSE a methodology for the automatic testing of cyber-physical energy systems is being developed. For an automatic validation, the specifications must be extended with information regarding the validation—scenarios and expected test results. Based on the validation scenarios and specifications appropriate tests are generated. The tests can be pure software test, but also a combination of software, hardware, and simulations. Of course, some manual setup may still be needed, especially if hardware is involved. For such cases user setup guidelines are generated. The engineering together with the automatic validation are shown as the *engineering* phase in Figure 1.

2.4 Enhanced Smart Grid Engineering using Machine Learning

The previously described methods are complemented with a cognitive learning approach, which provides further and user specific support during the design. Artificial intelligence provides an enlarged scope of possibilities for complex and large problem handling. Smart grid approaches, e.g. in electricity distribution, increase in complexity due to interoperability challenges in DER, Virtual Power Plants (VPP), and Energy Storage Systems (ESS) integration. Machine learning, as a branch of artificial intelligence, is able to handle such problems during the engineering process.

Using machine learning it is possible to reason about user decisions and actions. Consequently, typical design errors can be detected at an early stage and corrective actions can be suggested. Furthermore, solutions to recognized problems can be suggested and directly used by the engineer. With the usage of reinforcement machine learning, an algorithm, trained on the user design experience, can identify critical engineering steps. Another usage for machine learning could for example be the selection of suitable standards during the design phase. Unsupervised machine learning can be used to sort standards into clusters, and thus recommend suitable standards based on different parameters, such as use case and components, see Figure 2. In the end it is expected that the proposed solution can improve the user design experience and shorten development times even further.

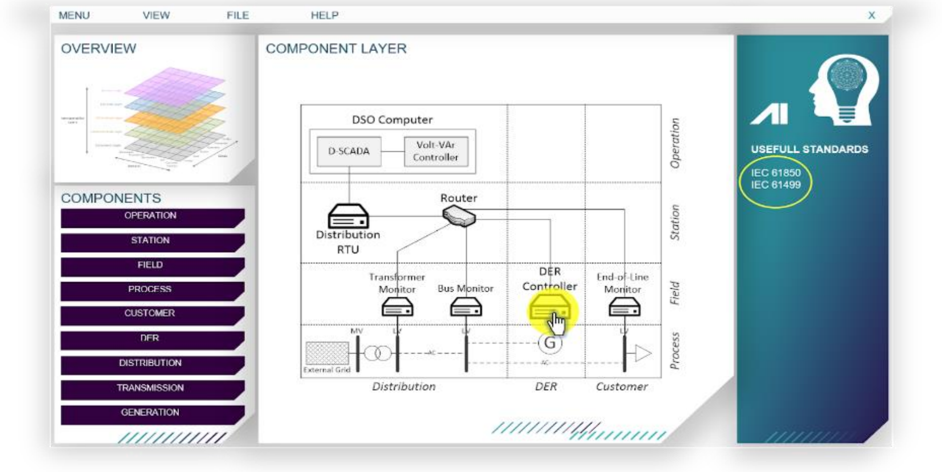

Figure 5. Possible use of a machine learning algorithm for suggestion of suitable standards.

3. Examples and Use Cases

This section presents a summary of two example use cases to highlight how the MESSE approach is intended to be used. More information about the two examples can be found in [9] and [12].

3.1 Engineering for Regional Energy Systems

Microgrids and regional energy systems are two domains where the proposed methodology will decrease the engineering effort. In order to show this, an illustrating example from the ELECTRA IRP project is shown. The main outcome of this project is a control concept called the "Web-of-Cells" (WoC) [13]. Among the control schemes that have been developed within the WoC approach, is a so-called Post-Primary Voltage Control (PPVC). The PPVC is running locally in a cell and handles voltage instabilities using two modes: *(i)* a "proactive" mode, using a look-ahead planning, and *(ii)* a "corrective" mode, which is triggered upon disturbances [14].

In Figure 3 the process from Figure 1 is applied for the development of the PPVC. In the first phase, design and specification are carried out by the engineer. This includes design of the two modes as well as network and communication configurations needed to connect to the control nodes. In the next step, these specifications are automatically enhanced with information needed for the validation, such as generated tests or simulation inputs. Based on the detailed—but still generic—configurations from the specification phase, platform and vendor specific configurations are created. This includes functionality and ICT configurations (e.g., setups for IEC 61850 or Modbus).

To test the generated configurations manual tests are combined with the generated tests. Some test results may also be automatically validated but in the end, it is the engineer who has the main responsibility. In Figure 3, this step is illustrated as part of the Factory Acceptance Test (FAT), but it can of course equally be part of the Site Acceptance Test (SAT). After the validation phase the developed cell controller is ready for deployment.

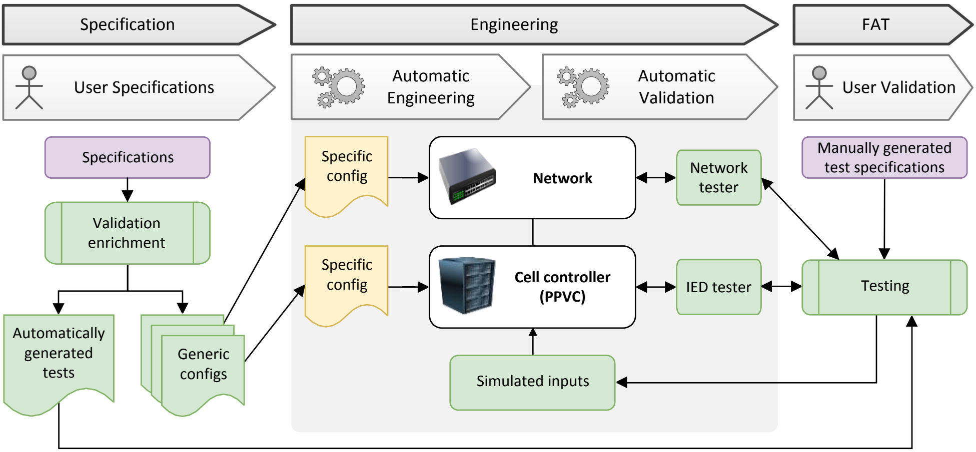

Figure 6. The model-based engineering approach applied to the development of the cell controller.

3.2 HMI Engineering and Validation

This example shows how generation and configuration of HMIs can benefit from a (partly) automated engineering process. Nowadays, all the configuration and validation steps are typically done manually and are thus error-prone, time consuming, and contribute to a large degree to the overall engineering costs. Two essential use cases are used to estimate the potential savings of an automated HMI engineering and validation support system:

- Use case *"Configuring a substation HMI"*: The substation HMI is a central point of a substation but is only needed when the substation is staffed (typically a substation is unmanned). Although seldom used, the HMI configuration accounts for a significant share in the total engineering costs. As a rough estimate, an average of 80 work hours can be assumed for the development of a substation HMI. If the substation HMI engineering could be largely automated, a reduction of at least 90% of this work is expected.

- Use case *"Testing the communication configuration from IED to HMI (FAT)"*: Typically, every data point should be tested from its entrance into the IED up to the HMI to guarantee its correct configuration. External test equipment is installed to simulate the signals on the input terminals. The appearance of the signal in the HMI is checked manually, which can be a very time-consuming job considering the thousands of signals that may be tested. Automating the data point tests would reduce the testing effort for the test engineer down to almost zero.

The following example shows how an automated generation and validation of a substation HMI can be established using the MESSE framework in a project setup based on IEC 61850. Due to their similarities, the envisaged MESSE support system can be applied to automate the engineering and validation of an HMI using the future standard IEC 61850-6-2. The current state of the standardization activities can be briefly described by Figure 4.

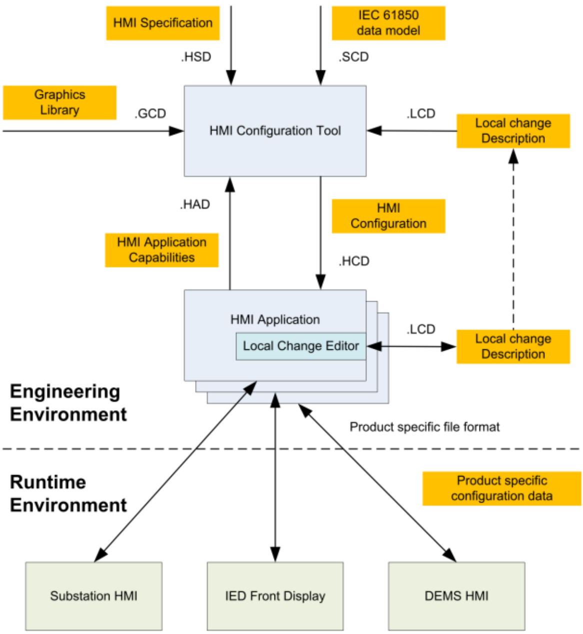

Figure 7. Draft IEC 61850-6-2 reference model for information flow in the design process (from [10])

The core principles of the standards propose to add XML-based descriptions of graphics and HMI mimics to the current power system descriptions. Thus, the extended IEC 61850 configuration format promises to be a perfect match for the formalized, machine-readable input specifications that are developed in MESSE (see left part of Figure 1).

The "Automatic Engineering" component, as the first part of the engineering phase in Figure 1, takes the role of the IEC 61850-6-2 "HMI Configuration Tool". It applies one or more model-to-model transformations to map the input specifications to the output model. To enable this automatism, rules are needed that defines how the IEC 61850 data points are mapped to the graphical elements of the HMI.

Additionally, MESSE's "Automatic Engineering" component can also generate tests. The tests are then driven by the "Automatic Validation" component of MESSE (see Figure 1), where the generated test program stimulates the data points in the IED (e.g., by controlling standard industry test equipment hardware). When the HMI receives data, and updates its user interface, it can additionally generate a log record describing the update that was made in the HMI. This HMI log can then be used for automated verification. This reduces the effort of the test engineer to almost zero

4. Conclusions

The complexity of the modern power grid is still increasing and focus is moving from a single system to a system of systems perspective. The results are increasing engineering efforts and escalating costs. To address these challenges, MESSE proposes the concept of an automated model-based engineering and validation framework that covers the overall development process of CPES, from specification and use case design, to automatic engineering and validation, and finally deployment and commissioning. The concept presented within this work can be well applicable to architecture and system development since it provides a solid foundation that fosters the formalized and systematic comparison of different development options. Based on a single set of test specifications and validation scenarios provided by the user in the initial specification phase, the test and validation framework generates test cases for each development option under investigation. Therefore, the model comparison is not restricted to architectural design decisions and its implications on the implementation but instead also comprises the results of the test executions.

As seen from the provided examples, the model-based engineering concept can automate many steps that are traditionally carried out manually. For example, the engineering and validation of substation HMIs is nowadays a very labour-intensive and error prone task which bears a huge potential for quality increase and cost decrease at the same time. Therefore, it is expected that the proposed approach will reduce the manual effort of developing smart grid applications and, in the end, reduce engineering complexity and costs.

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Peer2Peer im Quartier – Neue Handelsparadigmen in der Local Energy Community

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Kurzfassung

Das Projekt *Peer2Peer im Quartier* befasst sich mit der konkreten Umsetzung von Anwendungen zu Photovoltaik-Eigenverbrauchsoptimierung sowie Peer-to-Peer-Beziehungen auf Basis der Blockchain-Technologie in Quartieren und deren Validierung im Echtbetrieb. Die Vorteile dieser Entwicklungen reichen von Datensicherheit bis hin zu einer vertraulichen Abrechnungsplattform für Prosumer. Zusätzlich zu den dafür benötigten technischen Forschungen und Entwicklungen werden dazu passende Geschäftsmodelle für Infrastrukturbetreiber und Energieversorger definiert, diese im Testbetrieb validiert und, basierend darauf, Empfehlungen für künftige Konzepte ausgearbeitet.

Durch den Einsatz der Blockchain-Technologie eröffnen sich im Bereich der Anwendungen auf Quartiersebene völlig neue Möglichkeiten für schnelle und einfache Vertragsabschlüsse zwischen zwei oder mehreren Parteien, auf deren Basis ein Energiehandel und -austausch durchgeführt werden kann. Für die Realisierung dieser Peer-to-Peer-Beziehungen werden Rahmenbedingungen für digitale Verträge im Zuge des Projekts definiert sowie die Möglichkeit einer unkomplizierten Teilnahme beziehungsweise des Ausstiegs („easy-in/easy-out“) untersucht. Für eine optimale Usability wird in *Peer2Peer im Quartier* ein User Interface definiert und implementiert sowie im Anschluss den AnwenderInnen, die als lokale EnergielieferantInnen beziehungsweise -konsumentInnen dienen, zur Verfügung gestellt – potentielle Vertragspartner werden mittels Discovery-Mechanismen ermittelt. Zur Optimierung und bestmöglichen Nutzung der erzeugten Energie wird zusätzlich die Möglichkeit geschaffen, dass neben 1:1-Beziehungen auch n:m-Beziehungen durchführbar sind (mehrere LieferantInnen/ErzeugerInnen, mehrere KonsumentInnen/VerbraucherInn).

Das grundlegende Ziel des Projekts besteht in der Eigenverbrauchsoptimierung auf Quartiersebene und der Analyse, inwieweit sich die jeweiligen Peer-to-Peer-Anwendungen und das Gesamtoptimum im Quartier beziehungsweise an der Netzübergabestelle gegenüberstehen oder beeinflussen. In die Optimierung auf Quartiersebene fließen Nutzer- sowie Quartiers-Prognosen ein, die beispielsweise Verbrauchswerte für Werktage, Wochenenden und Feiertage sowie Urlaubszeiten oder Distanz- und Verbrauchswerte von Elektrofahrzeugen etc. berücksichtigen.

Parallel zu den technischen Entwicklungen werden Geschäftsmodelle für Wien Energie definiert und Schlüsselfaktoren für die Wirtschaftlichkeit der innovativen Lösungen ausgearbeitet.

Der Proof of Concept erfolgt im „*Viertel Zwei*“, einem Neubaugebiet im zweiten Wiener Gemeindebezirk. Neben Installationen der benötigten Infrastruktur (Photovoltaik-Anlage, Quartier-Elektrospeicher etc.) werden die Blockchain-Anwendungen im Feld ausgerollt und die Ergebnisse in der abschließenden Projektphase evaluiert, die Geschäftsmodelle überprüft und Empfehlungen für zukünftige Konzepte erarbeitet.

Danksagung

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Blockchain-Piloten der TenneT in Deutschland und den Niederlanden - ein Praxisbericht

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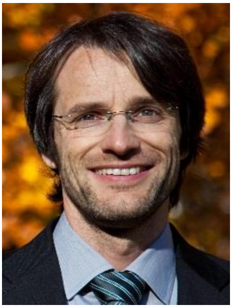
Spätestens seit der vermeintlichen Bitcoin-Blase ist Blockchain in aller Munde und auch in der Energiewirtschaft kann sich mittlerweile kaum jemand mehr dem Thema entziehen. Der niederländisch-deutsche Übertragungsnetzbetreiber TenneT hat daher bereits vor etwa 2 Jahren beschlossen über erste Pilotanwendungen im Rahmen seiner Crowd Balancing-Initiative erste praxisrelevante Erfahrungen mit der Blockchain-Technologie zu sammeln. Mit der Crowd Balancing-Initiative will TenneT grundsätzlich den Marktzutritt von kleinen dezentralen Flexibilitätsoptionen, wie Batteriespeicher, Wärmepumpen oder Elektrofahrzeuge, langfristig unterstützen. Beispiele hierfür sind TenneT's Beteiligung in den SINTEG-Projekten oder die erfolgreichen Pilotprojekte in den Niederlanden zur Bereitstellung von Primärregelleistung aus dezentralen Erzeugern, Speichern und Verbrauchern. Langfristig besteht dabei jedoch die Herausforderung Hunderttausenden oder gar Millionen an einzelnen Flexibilitätsanbietern den Marktzutritt zu ermöglich. Mit den vorhandenen Systemen und Prozessen, die heute bspw. für das Monitoring und die Verifizierung der erbrachten Systemdienstleistungen genutzt werden, wird dies nicht notwendigerweise machbar sein. Durch die Möglichkeit von bspw. einer gemeinsamen Administration einer Shared Ledger mit einer sicheren und vertrauenswürdigen Durchführung von Transaktionen verspricht Blockchain jedoch genau dies umsetzen oder zumindest unterstützen zu können. TenneT hat Anfang 2017 mit der Implementierung von zwei Blockchain-Piloten begonnen, um sowohl auf technologischer Ebene als auch im Zusammenhang mit rechtlichen und regulatorischen Fragestellungen sowie in Bezug auf Datenschutz und Datensicherheit Erfahrungen mit der Blockchain-Technologie gewinnen zu können. In Deutschland wird dabei gemeinsam mit der sonnen eServices GmbH die Nutzbarmachung von PV-Heimbatteriespeichern für Redispatch-Dienstleistungen im Rahmen des Engpassmanagements erprobt. In einem parallelen Pilotprojekt wird in den Niederlanden mit dem Ökostromlieferanten Vandebron die Bereitstellung von Sekundärregelleistung am kurzfristigen Regelarbeitsmarkt aus einer Flotte von Tesla Elektro-Fahrzeugen getestet. Beide Piloten nutzen Hyperledger Fabric, eine im Rahmen des Hyperledger-Projekts der Linux Foundation verfügbare Open-Source-Blockchain-Lösung.



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