currenTcy

BIOT's documentation to EWZ challenge 3

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ETH Zürich, 26.04.2018

Content

1 Disclaimer

The software code which is part of this report is open source and available at https://github.com/ETHBiots2018/currenTcy.

This project report was written as part of the spring 2018 course 'Blockchain And the Internet of Things (851-0591-01L)' run by M. Dapp, S. Klauser, and D. Helbing.

2 Introduction

2.1 Current Situation

Since the release of new CO_2 emission goals at the climate-conference in Paris of 2015, countries are forced to achieve very ambitious climate-goals. Their main restriction are CO_2-emission limits. One well-known opportunity to achieve these goals are renewable energy sources such as solar power plants, wind energy, etc. In Switzerland supply of electricity must be guaranteed by the local grid provider. Regular households can choose between different electricity mixes (basic, ecologic, solar...) but they cannot freely choose their grid provider. For industry customers (consumption bigger than 100000 kWh per year) the rules are different. These consumers have the possibility to freely choose their grid provider. They usually choose some sort of basic mix and then buy electricity certificates to verify their green energy awareness. These certificates should incentivize companies to buy more ecologic power to improve their image towards the public. Even though there is a great CO_2 emission awareness among people, the number of new solar power plant projects per year in Switzerland decreased over the last few years. This trend has several reasons. Not only does an owner of a solar power plant get less subsidies with every year passing but also loses a lot of money because of today's prevailing buyback situation. Considering it from a prosumer perspective reveals their disadvantage. Every kWh that is produced by a prosumer gets directly fed into the power grid. This kWh is compensated with a lower price compared to the price paid for energy that is bought back by the customer for his daily use.
According to ewz, in the region Zurich and Graubünden, the trading area of ewz, a lot of clients handed in complaints concerning the before mentioned buy-back situation. Ewz is therefore trying to find alternative ways to motivate citizens in their area of supply to invest in renewable energy sources. These means should lead to a clean energy composition and thereby to the achievement of a lower CO_2 emission per capita.
In the near future, society will face an even bigger challenge, namely the bad reputation of nuclear energy. The yet decided shutdown of nuclear power plants will leave a huge gap in the current electricity composition. To cover this gap, energy suppliers in Switzerland need to increase the attractiveness of investments into renewable energy solutions.
One upcoming and in the media very present technology called blockchain might provide the framework for a solution. Blockchain is a technology that enables secure transactions without involving a third party. Experts are talking about new decentralised networks, which are applicable in a wide range of areas. Not only does it improve data security for users but it also simplifies transactions and therefore the interaction between multiple parties in a big network.

2.2 Challenge

Looking at the BIOTS-challenges 2018, we were confronted with the following question:
How might the blockchain technology help to develop a reliable and highly efficient virtual energy solution that gives anyone the possibility to produce, store and use his/her own energy anywhere and anytime?

The task was to form a group of 5 to 8 people containing coders and non-coders eager to solve this problem by working out a suitable concept and afterwards achieving a fully executable program that makes use of blockchain protected transactions. We then formed a group of 7 people coming from different parts of Switzerland. All contributors are studying either mechanical or electrical engineering on the bachelor level at ETHZ.

2.3 Cutting-edge technologies provided by new market players

The following section gives a brief overview of a similar solution approach to energy storage problems by German grid operator Senec. Furthermore, two successful applications of the blockchain to organize the energy transition are presented. These existing projects were taken as inspiration for our own hack. One term always used in these projects is «prosumer» which plays with the fact that the client of the grid provider acts as both consumer and producer.

Senec

"Deutsche Energieversorgung GmbH", a German energy enterprise develops and produces intelligent power storage solutions under the brand name SENEC. In 2016 they launched a new product named "Senec Cloud". The idea of this product tackles the problem of peak and trough energy production over the year to the benefits of prosumers. When starting to use SENEC.Cloud 2.0, a power grid prosumer gets an energy account assigned. Power production increases the level of the energy balance on the account and power consumption decreases it. At the end of the year the imbalance of the net power production or consumption is settled according to the specific feed-in compensation. The prosumer attains autarky by using his own cloud stored energy and doesn't face the monetary losses that arise from selling the total energy produced and buying his total demand. Hereby the so called buyback problem is solved.

LO3

LO3 energy empowers communities through localized energy solutions using the blockchain.
One of their projects is the Brooklyn Microgrid in New York. In collaboration with Siemens they completely reimagine the traditional energy grid model, by coming up with the concept of a communal energy network. While the utility provider still maintains the electrical grid, the actual energy is generated, stored and traded locally by members of the community. This should lead to a more resilient and sustainable clean energy model.
Enexa is another project of LO3. The major concept is transactive energy, that uses blockchain technology to conduct energy transactions between prosumers. This creates a secure energy marketplace and effectively manages energy supply and demand on a local basis.

TenneT

TenneT's project tries to solve the instabilities of supply and demand caused by the entry of decentralized renewable energy sources into the power grid. Decentralized infeed of energy leads to transmission bottlenecks that are tackled with a smart management of the storage capacities. The blockchain technology offers new possibilities to securely and intelligently manage flows of electricity. TenneT and sonnen deliver the infrastructure including storage capacities, while the blockchain solution was developed by IBM.

3 Working process

As the description and goal of the challenge given by ewz was rather vague (see *2.2 Challenge*), there was no consensus of what the project should cover exactly. Especially the problems of physically storing energy seemed to be crucial to some of the group members. The argument was that the supply of renewable energies varies over different periods of the year, month and day depending on the weather, temperature, sun and so on. This fact also influences the price of the electricity since it is coupled to the electricity infeed and demand.

A talk between ewz and the group clarified the goal of the challenge. The physical aspect of the task shall be neglected since it's in the grid operators responsibility to maintain the needed capacity on the grid. The misbalances between the market price and the price for the prosumer will be balanced more or less over the year according to the ewz representatives. Their main interest is to acquire new clients and to encourage them to build and use new renewable energy power plants. As a result this project had to tackle only the accounting part of the project. The grid can be seen as a storage of «infinite» storing capacity.

A crucial point was the clear definition of «a prosumer». Three different models were developed during the project and are presented in chapters *4.1.1 Prosumer, 5.1 Limit of storage account* and *5.3 Microgrids.*

It was decided to neglect the legal aspects concerning different certificates, liberalisation of the market and current and future policy making as these important questions have to be answered by legal experts in the field.

Subsequently the first simple model was developed and the coding of the project started. As indicated on the front page three out of the seven members focussed on the coding part whose result is available on github (https://github.com/ETHBiots2018/currenTcy).

In parallel the other group members further refined the project and developed an easy understandable graphical explanation of the project (cf. 4.1.). Possible enhancements of the concept were discussed and are presented in the corresponding chapter.

The name «currenTcy» was chosen as project title to emphasize the focus on electricity and to point out that the virtual storage acts like an energy currency.

On Friday 16 of February the project was chosen by the judges as one of three projects on the «ewz challenge 3» to be pitched during the BIOTs final presentation.

In the following weeks this report was written.

4 Result

For an easier understanding of the implemented system an infographic was established which is further discussed in this chapter.

4.1 Conceptual model

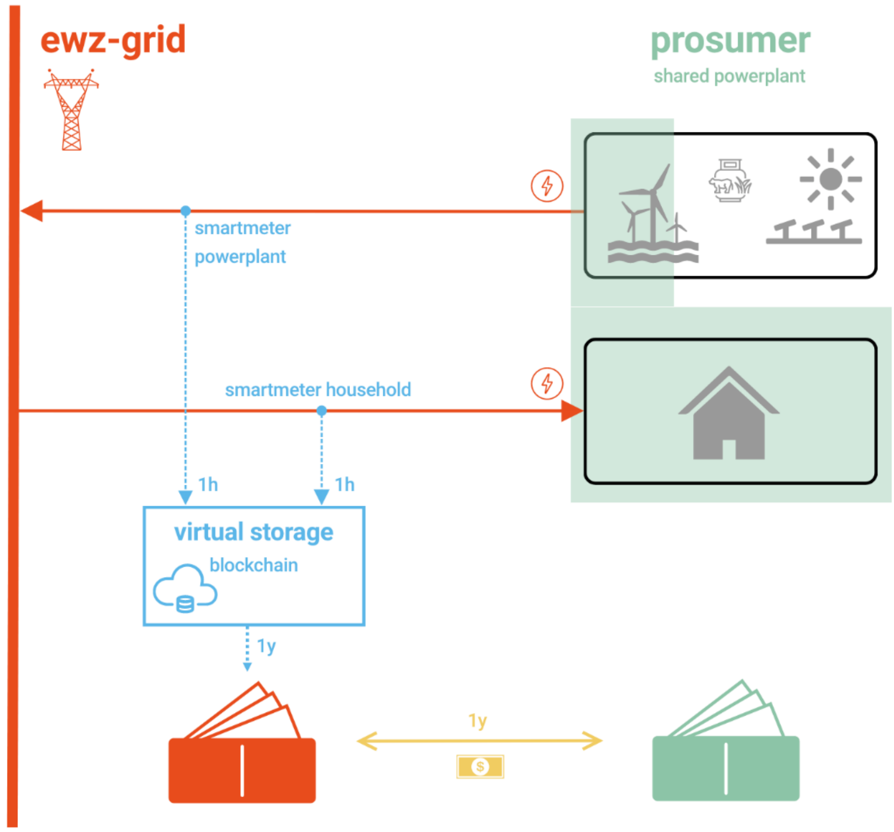

Figure 1 virtual storage concept

4.1.1 Prosumer

The whole concept lies on a number of households that want to invest in some sort of renewable energy production facility. For simplicity the system is explained only for one single prosumer which owns a percentage of a power plant (green). The interaction between ewz and other prosumers works exactly the same way as explained in this paragraph. This allows the vast scalability of the system. Prosumers depend on each other as they own power production facilities together. More precisely, investments can be made commonly in a crowd funding manner. For instance, households can share their own renewable energy projects or look for an investment opportunity on a crowd funding platform. For this project and the implementation however it is only important to make sure that at the moment of an energy transaction, it is known what fraction of the energy belongs to which prosumer. This means that this project does not come up with a funding or investment platform. This problem could be solved as part of a separate project.

Consider for example a neighbourhood consisting of different household which all wish to invest in a green future but don’t have the financial or spatial capabilities to run their own independent plant. By merging their means, they can jointly come up with the necessary money. Ewz takes the role of promoting the building of suitable groups. With this shared potential, prosumers are not limited by spatial or financial limits anymore. The plant may be nearby but can also be at a completely different location, if there is not enough space in the neighbourhood. This is a crucial idea for urban environments. Everyone participating in the financing owns a percentage (according to the amount of money they spent into the plant) of the power produced by the plant. Therefore a system with two smart meters per customer is used, which count on one hand the consumption and on the other hand the production of power (as a percentage of the overall production of the plant) by the prosumer. Holding multiple shares and receiving energy from different places increases the autonomy to other energy resources and strengthens the renewable energy usage of every single customer.

4.1.2 Ewz grid

This project doesn’t propose any change to the grid. The gridis to be considered as an infinite sink from the power plant side and as an infinite source from the consumer side, not caring at all about the physical aspect of power distribution. The grid further provides the link between the plants and consumer. There's no other physical link between them.

4.1.3 Virtual storage

Virtual storage is an energy accounting system, in this case implemented on a blockchain. Every prosumer gets assigned an account that at every instance shows his net consumption or production of energy in the current year. As discussed in chapter 4.1.1 the prosumer consists of a production- and a consumption site. We therefore place a smart meter on each side which continuously measures production and consumption. The smart meters store the data internally and write it (cf. 5.4) periodically to the blockchain. The smart contract sitting in the blockchain does then the following: compute the share of the consumer of the overall production and compute the difference between production and consumption over the last period. These numbers are then written as a transaction to the blockchain.
The process of storing the data is done after a freely definable period of time. Taking into consideration the transaction costs of Ethereum's blockchain system, we propose to do it once an hour, since too many transactions are costly and therefore undesirable. Still one has to be aware of the fact that a smaller time period reduces the danger of possible manipulation of the numbers when they are only stored in the smart meter. Since this project is mainly conceptual we did not define a fixed period.
The grid operator will sell the virtual storage as a product to his clients for a price which reflects all the costs of its operation.

4.1.4 Clearing

Like in nowadays systems there has to be some sort of clearing between the grid operator and the client after a certain time. We propose to annually check the balance of the prosumer. On one hand there will be prosumers with an over-consumption (negative balance), who need to pay for the outstanding amount at the end. On the other hand, clients with a positive balance (still some power left in the virtual stock), who get paid out in the end of the year. There may also be introduced a bonus for ecological behaviour in terms of higher prices per unit for over-consumption or lower prices for people with positive balances. The details of the overall accounting process should be clarified by experts. One benefit of the system is the avoidance of the buyback situation.

4.2 Project implementation

4.2.1 General information

To generate his own local blockchain the tool «Ganache» was installed on every developers working station which then could be accessed through «MetaMask». In addition to this the «truffle» framework was used which is especially designed for working with the Ethereum blockchain. For the frontend design JavaScript «mithril» was chosen as it's perfect to rapidly develop small online tools and already worked fine in past projects. The contract was written in the solidity language with version 0.4.4. The communication between the contract and the webfrontend was established through the «web3» and «truffle» frameworks.

4.2.2 CurrenTcy contract

In the framework of this project, prosumers are represented by an address, that owns a certain amount of «currenTcy». Another entity, that is represented by an address is the smart meter. Smart meters have to be registered to avoid manipulability of the system. For the verification of the smart meters a Boolean was introduced. Setting this boolean to true means that the grid provider trusts the data received by that smart meter. Two types of smart meters are distinguished. Consuming smart meters are mapped to only one owner, whereas producing smart meters are mapped to multiple owners. The struct «PowerPlant» manages the ownership of a producing smart meter by multiple prosumers. Finally power plants are as well represented by addresses. They map the ownership of shares at this power plant to a certain prosumer address.

Ewz as grid owner gets the following exclusive capabilities. Setting and getting a smart meter to a user, as well as registering and unregistering smart meters. They are able to add new power plants and thus declaring ownership of it according to shares. If a user retrieves from a share of a power plant, ewz can remove that user from an existing power plant.

The capabilities of the smart meters are the following. They credit stored user addresses with the energy token for a certain amount of energy produced. So far watt-hour to token conversion is one to one, which means that different energy sources aren’t weighted with different energy rewards. The conversion factor can arbitrary be adapted to for example give preference to some kind of energy source.

4.2.3 Web interface

The following figures give a brief insight into the web interface and the different aspects of power plant and prosumer management. It is important to state that some interfaces are exclusively accessible for ewz ,which is the central administration entity. Figures 2 and 3 in this section and the figures in the Appendix show the power plant and prosumer administration pages of the web interface.

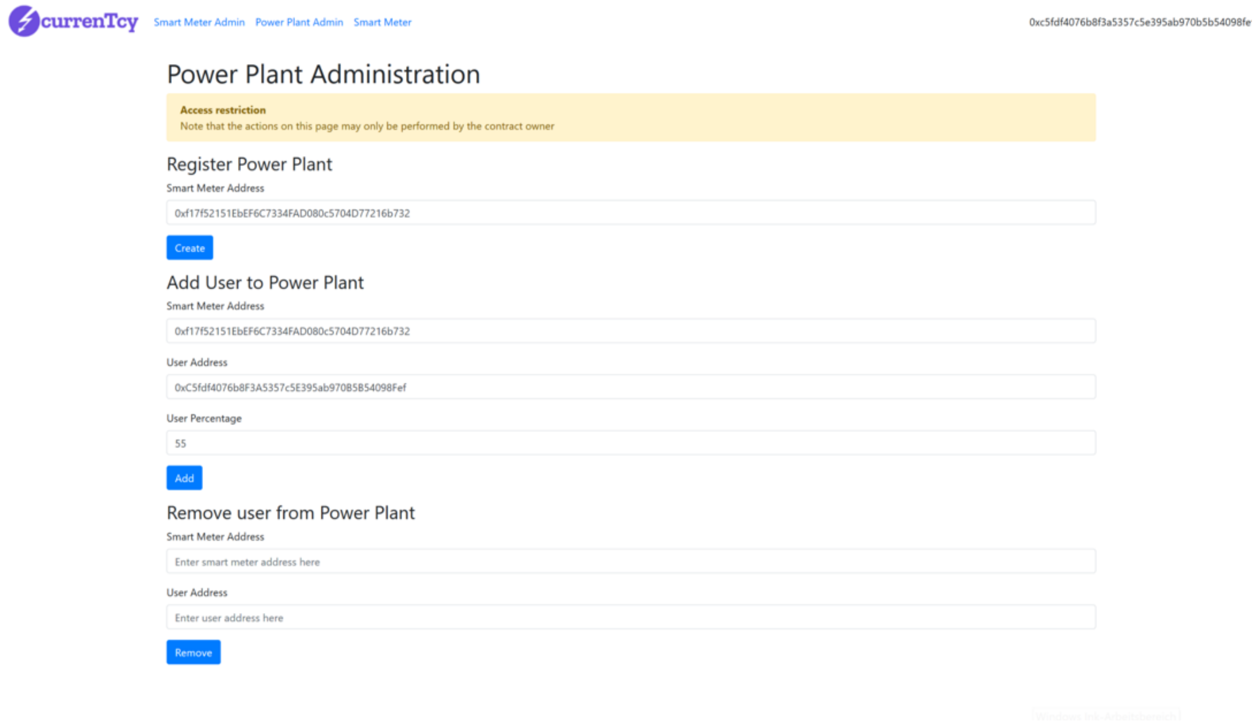

Figure 2 web interface, power plant administration

Figure 3 web interface, power balance

5 Evaluation and enhancement possibilities

By using the blockchain as a transaction management system, the presented implementation allows ewz customers to avoid the transaction losses of buying and selling the electricity. Recent sale pitches of other firms and other experiments proof that blockchain technology could be even more beneficially used than in our prototype implementation. This chapter summarizes further brainstorming of the team and hereby presents even more consumer-friendly solutions.

5.1 Limit of storage account

As an addition to the previous presented basic model, where the prosumers virtual storage has no limit, there could be introduced a sales model with different types (sizes) of storages. Prosumers could choose which storage model fits them the best and would buy a yearly subscription depending on the amount of energy they are allowed to store. Obviously the size someone prefers depends on the amount of renewable energy they own.
The grid operator defines the prices for the according to the storage capabilities. The higher prices can be justified because the more energy someone stores on his account, the higher are the costs for the supplier to regulate energy flows in the grid, especially with todays very time-/season-dependent energy resources as for example solar power. This charge can be seen as a compensation for the grid providers losses of not using the buyback system anymore.

5.2 Trading of power plant shares

A further logical step to extend the offer could be the introduction of power plant shares. If a client is willing to invest more money in renewable energies to increase the stock during low-sun or low-energy seasons, a power plant stock market could be a desirable solution. Depending on the demand of power of prosumers, power plant shares can flexibly change their value.
Imagine that it is already November. Costumer A doesn't need as much power anymore because he moved to an apartment. Customer B just bought a second holiday domicile in the mountains such that his power consumption doubled. Costumer B doesn’t want to have a negative energy balance in the end of the year, due to the thereby arising clearing costs. Therefore costumer B buys some power plant shares of costumer A by paying the current market price. This way everyone is better off. Customer one doesn’t overfill his storage which may be limited to a certain energy level and customer B avoids the costly clearing of a deficit in the end of the year. With our virtual storage implementation balances get automatically adjusted to the new circumstances.

5.3 Microgrids

The Brooklyn Microgrid experiment (cf. 2.3) is the basis of a next possibility to further evolve this project. So far prosumers and ewz as a grid provider act in a huge distribution network. Energy is exchanged among everyone without any local restriction. The concept of microgrids is to divide the large distribution network in to smaller sub-networks, the microgrids, wherein prosumers buy and sell their energy. The proximity brings the advantage of lower transmission losses, due to diminishing use of long transmission lines. Energy sources in microgrids are mostly renewable as they are so far mostly using PV energy. Reliance on renewable energy sources is connected to higher vulnerability to external factors as for example weather conditions. If for example a region highly relies on wind power and if there is suddenly a period of no wind, this can lead to a situation in which the microgrid is no longer able to work independently. A similar scenario is imaginable with solar power. Therefore transmission lines shall not be given up, since they can be used to balance certain microgrids under adverse circumstances. The microgrids are hereby interconnected to a way bigger grid via the so far used infrastructure. This makes stabilization of all systems possible. Besides the lower transmission losses, there is another advantage of microgrids. Dividing the system in smaller subsystems mitigates the impact of an outage of a certain part of the grid. Smoothly working microgrids are not affected by an outage in other microgrids. Thus the grid provider can guarantee higher reliability and security of supply to the end customer. Our implementation of the blockchain managed virtual storage finds perfect applicability to organise the prosumers in one microgrid. In a global perspective with the multiple microgrids, there is still an entity like a grid provider needed, to stabilize the imbalance in the whole system. If ewz divides its grid into microgrids, it could still act as a manager of the whole system.

5.4 Direct data storage via smart meters / security

An aspect which isn't covered in this implementation, but which is however worth mentionning, is the precise dataflow from the smart meters to the blockchain. We imagine the data flow as follows: The smart meter has an internal processor and storage possibilities as well as a link (e.g. LoRa) to the IoT. The link could also be implemented (if available) over local WIFI network to minimize the costs. With these three key elements it should be possible to be able to write directly to the blockchain without using any intermediate and vulnerable gateway. Even with this solution we identify the smart meters still as the most insecure part of our system.

6 Conclusion

6.1 Usage of blockchain

The model presented in previous sections uses the blockchain as a secure way of saving the balance. It's clear that this system could also be implemented as a traditional client-server system with another data structure. During the week we observed several cases where in our view a better idea would be to design the system without the usage of the blockchain technology. Nevertheless, using blockchain can clearly enhance the trust of a customer to a service but at the price of a slower synchronization. Additionaly you have to pay a certain gas price usually. With Ethereum we have a confirmation time of 29 seconds, which is relatively fast compared to other blockchain suppliers. However, for our model there is no need of fast confirmation, the period after which the new balance gets uploaded is far larger anyway (in our example 1h). Looking at the prices for mining the transaction, we should also encounter no bigger problems. As already mentioned, the mining gas price can be kept low by just not too frequently updating the balance. Another important aspect related to our virtual storages on blockchain is the transparency and anonymity of this technology. If a person shares his or her wallet address stored in a public blockchain, it will be possible for anyone to see all the input and output transactions. Whereas for an average user this possibly isn't a big problem, for businesses such a situation might be critical.
Blockchain technology is often criticised for the large amount of wasted energy. This fact would reduce the ecological benefit of the project. As different speakers of the BIOTS week pointed out, this issue will diminish in future since new technologies are developed.
Finally, companies eager on using blockchain also know about the marketing effect of the word «blockchain» and want to use the current hype around this term to their advantage. For companies, like ewz, blockchain can have great potential, opening a new door to new not yet discovered markets. Projects like this could mark a beginning.

6.2 Disruptive effects on a system level

As ewz is a traditional player on the market their aim is not to suffer a strong disruption in their field. The most disruptive technology would clearly be the peer-to-peer (cf. 5.2, 5.3) network where ewz would provide only the hardware and wouldn't be involved in the trade of the power. In our opinion it makes sense to not completely disrupt the traditional system to a distributed system because there clearly is a need for a central authority which ensures the stability of the power grid. Private «prosumers» will never be able to offer large storage capacities (barrier lakes, nuclear, power to gas...) to smooth the power peaks on the grid.
We therefore favour the solution where clients can produce their own renewable energy but don't need immense financial capabilities. Additionally by using the virtual storage ewz can increase the amount of green energy in their portfolio and compensate at least some of the missing energy after the forthcoming shutdown of the nuclear power plants.
The concept of virtual storage offers opportunities to both ewz and the client. For ewz it's a new business opportunity where they can earn money in a flat rate like manner. In fact our proposed model adapts the

role of ewz and the role of the client as both of them can be seen as a consumer and a producer of electricity.
We also see it as a first step towards a more radical change in the electricity market. We could imagine that ewz will control storage possibilities at the client side (e.g. Electric cars) and even part of their electricity as for example they decide when the boiler of a house should heat. Our smart contract can be adapted for new ideas and the client has always full access to all data.

6.3 Review

The project has been informative related to blockchain technology and in our case energy supply in Switzerland and the ewz grid. Thanks to the presentations in the beginning of the week, we got a slight insight into blockchain technology and its different areas of application. Our group was also invited to present the project at an «ewz innovation event» which was held in Zurich and where national and international experts in the fields of grid operation and blockchain were present.
In the discussion with the people of ewz we got a first glance into the electricity market. The business model of power suppliers remained approximately the same for around 100 years. Because of this long period of almost no innovation there is much room for new ideas and models. Some of them are quite radical while others look for a smoother change. In conclusion to this, the traditional stakeholders are quite nervous and try to find themselves new solutions before new players invade their business. In our opinion finding an overall solution to all problems won't be possible neither for the traditional grid operator nor for new players. New players don't have the financial capabilities and infrastructure to run a power grid whereas the traditional stakeholders are not enough innovative and agile to face the rapid revolution of renewable energies.
As in many fields they both will need to collaborate. The idea of ewz to go on a hackathon like BIOTS and to present their problems can be seen as a first step towards the needed interaction between different actors.

7 Appendix

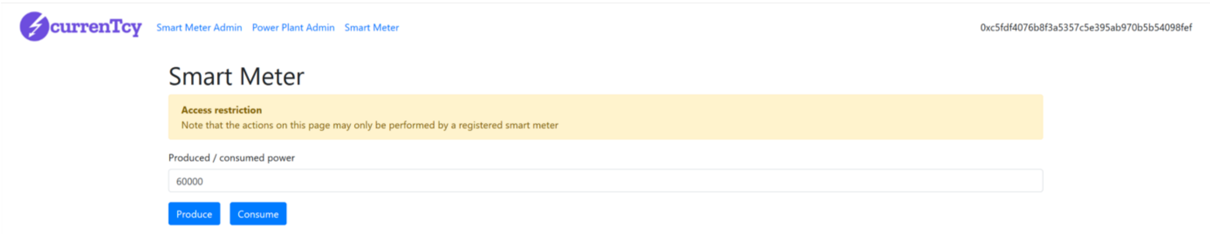

Figure 4 web interface, smart meter handling

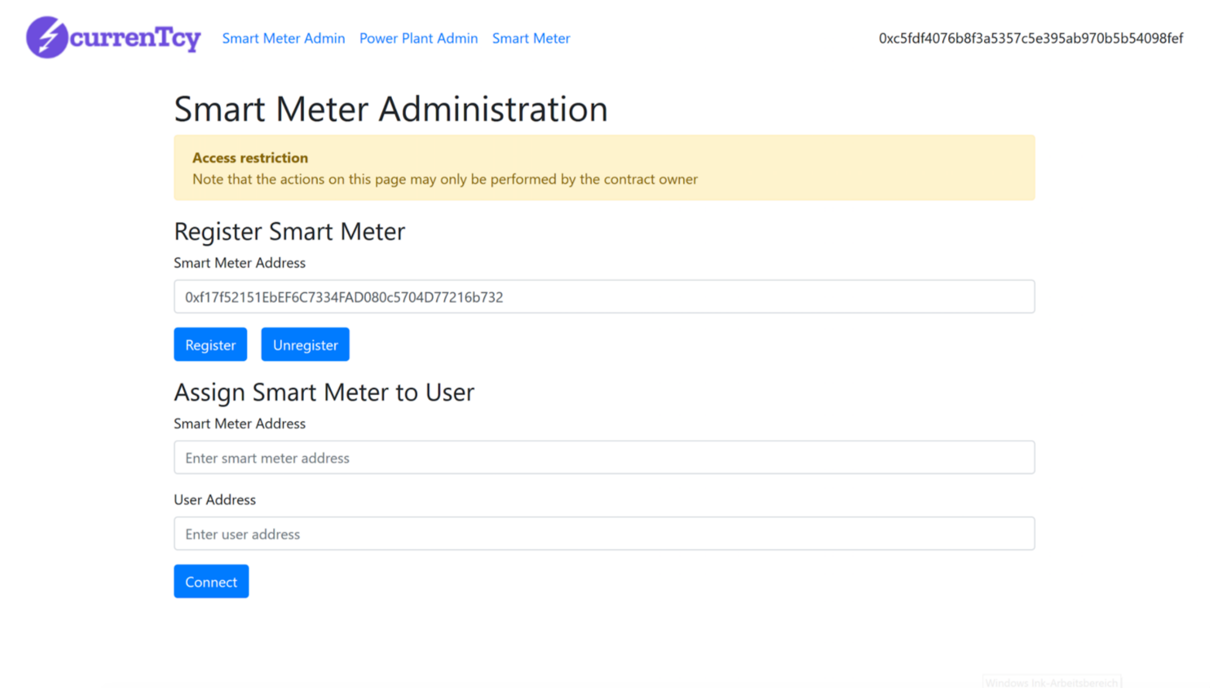

Figure 5 web interface, smart meter administration

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9 Figures