Blockchain Technology in Solar Manufacturing

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***Abstract* —** *Blockchain transactions are documented in an immortal decentralised format and monitored securely. In solar manufacturing, it enables the visibility and ability to trace the product information as they move through the value chain. Once the transactions have been updated in the distribution ledger nodes, the information gets tamper-proof that connects via the cloud using the Internet of Things (IoT). Since the retained information of the products has been tracked in the cloud, transparency towards the customer becomes very high. It also protects the brand name from counterfeit and avoids the Grey market. In this paper, we conduct an analytical review of literature for keeping the brand value, quality, customer satisfaction and cost reduction using blockchain, and suggest some future direction towards emerging technology with blockchain. The analysis indicates that the awareness of blockchain in the manufacturing industry is deficient, and there is a high resistance of acceptance in blockchain technology.*

Keywords*: Blockchain, Photovoltaic Manufacturing, Technology*

INTRODUCTION

Blockchain is a secured transaction that stores information via cryptographic algorithms. Once the data have been updated in the nodes, the encrypted immutability data become tamper-proof in the value chain. Additionally, the data is protected in distributed ledger technology along with a timestamp and gets audited immediately in the system. In the value procreation, blockchain technology provides operational efficiency, new business models, collaboration and transparency. Moreover, it enables a new level of trust with the customers.

The blockchain application started from bitcoin and it is moving towards Industry 4.0 integration with IoT and Artificial Intelligence (AI) along with smart contracts. In Solar Photovoltaic manufacturing lifecycle, blockchain gets linked to procurement processes, production information, quality details, logistic transactions and acceptance of the product by the end-customer. In each method, the transactions run on cyberspace with independent computers and provide a holistic view of the end-to-end manufactured products.

In solar module manufacturing, blockchain process is used for incoming material live-tracking, eliminates the quality check time and improves the inventory lead-time. In the production stage, it captures live final product quality information and transfers live data to the nodes, which is further linked to supply chain and smart contracts "Fig. 1". By adopting blockchain, it reduces the cost, time and provides real-time transparency in the process. Moreover, it improves trust in the network and effectually, helps managers to take the right decision in the value chain. It also helps the government to validate the product and do live adulting for domestic content requirement (DCR) [1] in manufactured modules.

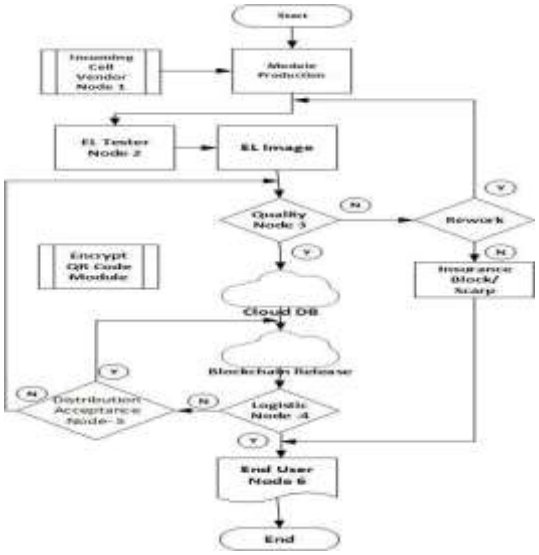

Fig 1: Flow Chart (Pv Manufactring Blolckchin)

BLOCKCHAIN IN INDUSTRY 4.0

In Industry 4.0, blockchain plays an essential role for smart manufacturing [2]-[1] in aligning with IoT [3]-[1], it also enables physical-cyber-systems to connect nodes, fog computing and manages distributed decision support system [4]-[1]. It also includes an immutable ledger, transparency, authenticity, decentralisation, distribution and anonymously. Transactions data can be automated through IoT technology and is linked to smart contracts, however, it gives more significant impacts of using AI and Bigdata [5] to the blockchain technology. Once the data are shared and updated in the nodes, the exchange happens on the pear-to-pear nodes and gets broadcast to the complete network for the validation [6]. It also provides transparency to users.

Protecting real-time data through blockchain application distributed ledger, improves the autonomy, trust and co-participation [3]-[2], [7]. In manufacturing, connecting Industrial Internet of Thinking (IIoT) [8] with blockchain is the ideal solution for advanced security. It is an effective technology for providing security and privacy in the IoT [9] environment and leads to cloud manufacturing [10]. Once the secured data has reformatted to hash data, then the encapsulated hash data gets transmitted to the decentralised ledger with cryptographic algorithms. On the other hand, the quantum algorithm may be able to break the security of the encryption [11] in the blockchain and lead to data vulnerability.

I. TECHNOLOGY BINDING

Blockchain technology provides real-time transparency and saves costs to safeguard the sustainability of manufacturing [12]. At the same time, it reduces verification and networking cost. It also achieves higher yield, improves the quality, optimises the process and provides trust in the manufacturing value chain [2]-[2]. In the blockchain, smart contract reduces administration cost, settlement time, faster binding contract and avoid human error [13] in the public network.

Blockchain can abridge the gap, integrate with different technology and improve the decision-making in the business [14]-[1]. It also provides ethical and tamper-proof data in the network chain, especially training the ethical data in Artificial Intelligence (AI) and provides transparency [15] in the decision-making.

On the innovation side, one technology helps another one that leads to the sustainable development of the products [16]. Blockchain is an emerging technology that links to various other technologies and applications like enterprise resource planning ERP [14]-[2] and Cyber-physical system [4]-[2]. Through the application program interface API [17], blockchain application can integrate by distributing business process integration [18], connect cross-business [19] and pear-to-pear network of the manufacturing process. For instance, as a result of blockchain integration with logistic and insurance [20], calming insurance amount can be done on spot without any paperwork or investigation.

TRANSPARENCY IN PHOTOVOLTAIC MANUFACTURING

Photovoltaic modules Bill of Materials (BOM) contains cells, glass, front and back Ethylene Vinyl Acetate (EVA) sheet, back white sheet, frames and junction box. Each module has been identified by hexadecimal serial number, barcoded and tagged along with lamination process. In the final product, this serial number is merged with product code, wattage, order, date and line along with technical test parameters like efficiency, temperature, Voc, Isc, Pmax, Vpm, Ipm, FF, Eff,m, Eff.c, Rs, Rsh and MCC1 “Fig. 2” . The testing parameters are also recorded and transmitted in radio-frequency identification (RFID) tags and moved along with each module. The information that has tagged in the RFID are tamper-proof, but there are certain limitations for using RFID by the end customers. For instance, it cannot carry the final Electroluminescence (EL) image “Fig- 3” of the module because the file size is high. The information which is carried in the modules are limited to the quality of the product.

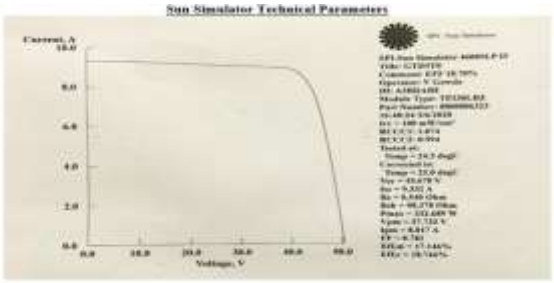

Fig 2: Testing Parameter (Sun Simulator Technical Parameter)

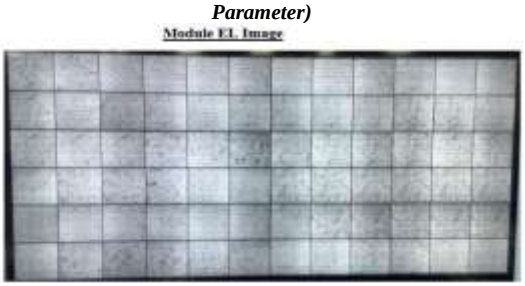

Fig 3: EL Image (Electroluminescence Images of A Photovoltaic Module)

The Track and trace with blockchain process in modules are designed and defined in the process. It starts from the critical inputs like the detail of cell manufactures, the detail of quality, EL images and EL parameters. The information is captured live from the production line through encrypted data via API's (SAP-PP and visual management systems) and then transmitted to the nodes with all the relevant parameters. The product details are stored in SQL cloud server and linked with the Microsoft Asure Blockchain workbench "Fig. 4" which supported by Ethereum. The web app is the interface control part that connects user interface (UI), data and the blockchain. The weblink acts as permission-based nodes to get access to the particular block. The smart-contract would provide the acceptance of the product in the chain. Once the encrypted cryptography code is linked to the product code, the complete chain can be tracked live and monitored by the user. In the pear-to-peer process, if particular modules are damaged or stolen, then the same product status can be declared immediately in the respective nodes. In future, if anyone verifies the product in the cloud, the information of the verified person will be tracked and notified immediately to the respective legal team.

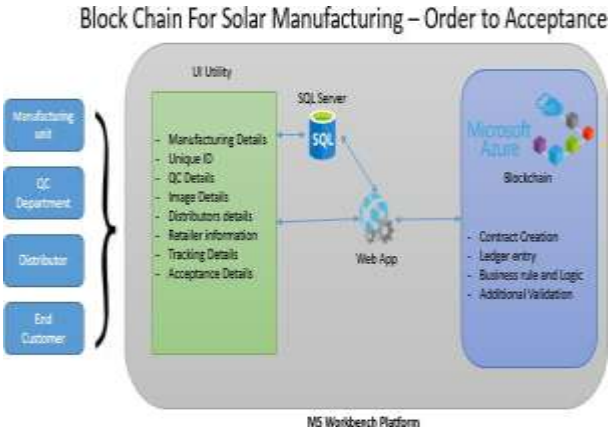

Fig 4: Azure MS Workbench (Blockchain High Level Processs- Order to Acceptance)

EMERGING PROCESS IN BLOCKCHAIN

In the supply chain, the distribution ledger will update the tracking process of the location and movement of the logistics. In simple, the waybill process can be integrated into the supply chain process and create business rules to link in the ledger entry of the contract. Therefore the public key was shared to the peer-to-peer nodes to access the product movement from one location to another location. While sharing the public key, accountability of the product and ownership will be tracked in the ledger, then link gets transferred to the smart contract. In the process, the new business rules integration can be linked to other nodes. For example, linking insurance nodes to the public chain and if any damage or theft happens, an immediate settlement will be cleared by the insurance and smart contract would get updated by the insurance node. In the defined business rule process, blockchain will emerge and manage the ecosystem in the value chain.

BENEFITS OF BLOCKCHAIN

In the current process, the public has limited PV product transparency in the value chain. A few customers audit the products randomly in the production stage, or it gets verified by the third party certificates against the specific model of the products. Warranty and services of the product are identified on proof of sales; hence, traceability between the distributor and customer is always a challenge including product tracking and monitoring. By implementing blockchain, the transaction would get recorded and validated live in each transaction then all transactions get authorised regardless of the need of the third party and the advantage of decentralisation technologies. The controlled set of users have the privileges to validate and verify the transactions in the blockchain. This permits blockchain to have some benefits over the public blockchain. It also gives the ability to split the network into segments where only a subset of nodes needs to validate the data to a particular application and allows the use of cyber-physical-system for better scaling. Moreover, the validated nodes can be trusted, allowed the use of the consensus algorithm that offers much more throughput.

CONCLUSIONS

The paper highlights the concept of "Blockchain technology in Solar Photovoltaic Manufacturing", which provides a conceptual answer to secured and organised data generated through the end-to-end transparency process in the solar photovoltaic industry. In addition, it adds to the research to provide the potential of blockchain in order to acceptance of the complete value-chain. In the value proposition, adopting new technology will reduce the

time and cost, then increase the brand name from market value, moreover, the trust and transparency will increase in the organisation. The concept of blockchain in solar PV modules product has been designed in an architectural proof-of-concept. It also helps the government to validate the product and do live auditing for Domestic Content Requirement (DCR) in manufactured modules. In the same time, it is also to identify counterfeit and black-market, and protect the solar market. In the process, the blockchain reduces the administrative paperwork, improves the efficacy and gives full transparency to the customer to enhance the product quality and identify the authenticity of the product. However, the adoption of the block chain is still in the preventive stage of the emerging technology.

The study is limited to proof of concept in blockchain under module manufacturing process, and it is under the implementation and prototype stage.

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