An Information Model of Power Distribution IoT and Its Application

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Abstract. Power distribution of Internet of Thing technology develops quickly nowadays, however, the basic information structure of power distribution IoT is still in research and development. This article raises a new information model of Power Distribution IoT and discusses logical topology, matching of measurement value for measurement point and isomorphic model of map location, it provides a consistent algorithm for information model of power distribution IoT as well. Based on existed research, a new hypothesis is raised, which focuses on the structure of connected data product of power distribution IoT and it discusses the process of how to realize the architecture further. Lastly, article introduces a successful research and development case of information model of Power Distribution IoT to prove practicability of it.

1. Introduction

The core of Energy Internet is electricity, it is an intelligent network in new generation which is a profound combination of energy and information and connectivity, Energy Internet makes “make various energy complementary crosswise, achieve storage harmony vertically” realized[1]. The most important and obvious trait of Energy Internet is the combination of energy flow and information flow[2]. So far, the business pattern of energy interconnection is focused on energy production, exchange and usage. Business companies acquire lots of information about interconnection in Energy Internet field, information acquirement, information transmission and information storage safety are still in work priority, the excavation of potential value and processes of information flow and location flow combination still get room for improvement[3]. Especially in information model of power distribution IoT(DIoT), which has strong connection with users’ feedback, with generation and development of new concept about intelligent IoT[4], it is an urgent and important task to have research on information model of DIoT. Therefore, this article develops research on construction and application of information model of DIoT.

It discusses about research status and existed challenges in field of information model of power distribution IoT in the first section of this article. In the second section, it raises a new information model of DIoT and discusses Logical Topology, matching of measurement value for measurement point and isomorphic model of map location, It provides a consistent algorithm for information model of power distribution IoT and an algorithm model of even-triggered automatic collation as well. Thirdly, it mentions about data product structure of information model of power distribution IoT and makes a further discussion about coordination within information mode and systematic structure. In
the fourth section, it gives an application of information model of power distribution IoT system. There are final statement and further research in the last section.

2. Information Model of Power Distribution IoT System

According to analysis about distribution utilities business in city and actual application, we found that: in order to satisfy realistic demand, topological of power network, acquired data from device measurement and location based service are combined in one data product in general. Therefore, it raises formalized definition about information model of power distribution IoT based on the definition in [5]. Then, it defines model’s consistency related to unexpected situation in rule bank, it discusses the consistent algorithm for information model of power distribution IoT and an algorithm model of even-triggered automatic collection.

Definition 1: DIoT=(Top, Msm, Loc), Top is the Logical Topology sub-model of DIoT, Msm is the measurement sub-model of DIoT, Loc is map location sub-model of DIoT. The question about consistency of marketing and distribution model in practice can be abstracted to consistency of DIoT sub-model. For an entity “En” of DIoT, sub-model of Top describes logical location and universal attribute of certain subject of DIoT, which is En, in entire topological model. The universal attributes cover the electricity meter information about topological location in distribution and the number of meters, settlement date, manufacturer and so on. Sub-model of Msm describes various, real-time, measured attributes of certain subject of DIoT ---- En, it can be compared to three attributes in electricity meter, which is electric current, voltage and blackout. Sub-model of Loc describes map attribute of subject of DIoT ---- En, like settlement location of electricity meter and real-time working location of emergency crew.

Definition 2. Top=(Iden, Par, Son, ComAtti), Iden is the only identification of entity En, Par is the entity supertype of entity En, Son is the fruit of entity En, ComAtti is the universal attribute of entity En. For example, transformation relationship can be concluded from calculation of transformer substation and circuit relationship and calculation of circuit and courts relationship.

Definition 3. Msm=(Iden, TimeStamp, MsmPoint, MsmValue), Iden is the only identification of an entity En, TimeStamp is measured timestamp, MsmPoint is the number of measurement, MsmValue is measured result of entity En in certain timing (TimeStamp) and certain measurement (MsnPoint). For instance, voltage is 219.6V at 21:37:38 on June 1st, 2020 in measurement point 1035627.

Definition 4. Loc=(Iden, TimeStamp, LocPoint, Role), definition of Iden and TimeStamp is the same to what mentioned above, LocPoint is the real-time location of hypostatic En, Role is access authority of entity En in certain time stamp (TimeStamp) and certain location (LocPoint). For example, user 10235627 is able to create, read, update and delete data, which is in fundamental files of measurement point 1035627 within 500 meters. Passive measurement value is created by Msm sub-model and active access authority of data is created by Loc for entity En. For consistency of defined model, the unexpected business rule bank has to be defined as well.

Definition 5. Unexpected business rule bank. NBRL=(No, En, Rulebasic(En), Ruletree(En)), Rulebasic here is rule of unexpected business for the single hypostatic En. Ruletree is business rule in attribute relationship for entity En and the parent-node of En.

Algorithm 1. Criterion of model’s consistency algorithm

Input: DIoT model

Output: judgement result

Step 1. For all hypostatic En located in leaf nodes in sub-model TOP, acquire measurement result (Msn i) of corresponding sub-model of specific En in condition of present time stamps.

Step 2. For an entity En, get measurement result (Msn j) under circumstances that its sub-model TOP is at parent-node Par(En) in present time stamps.

Step 3. If measurement results of Msn i and Msn j are not under the range of unexpected business rule bank, so determine sub-model TOP and sub-model Msm of entity En to be consistent.

Step 4. If measurement results of Msn i and Msn j are under the range of unexpected business rule bank, so use the active collation algorithm, collation demand is created, adding a record to data collation base at the same time.
Step 5. Dismiss related record in data collation base when the active collation triggered by
demanded proofread.

Step 6. For all entity En in sub-model Top, if conclusion can be made from provided consistency
between sub-model Top and sub-model Msm, the DIoT model is consistent. Vice versa.

Due to unnecessariness of tracing to the source forward after calculating the root of every entity En,
therefore, the worst time complexity of algorithm 1 is caused by the maximum amount (n) of entity En
and the maximum traceable length of leaf node, so, record the algorithm complexity as O(n*k).

Algorithm 2. Algorithm model of even-triggered automatic collation

Input: unexpected measured result
Output: adjusted DIoT model

Step 1. Extract Msm sub-model and Top sub-model from coordinated entity En based on entering
unexpected measured result

Step 2. Acquire results of entity En in sub-model Top from parent-node Par (En) and sub-node Son
(En)

Step 3. Acquire measured result from measurement point of Par (En) and Son (En) under Msm
model

Step 4. Acquire authorized information about Term collation within range of Loc (En) under Loc
sub-model and send the collated work order

Step 5. If collated term Term executes collated work order successfully, then adjust the DIoT
model; If does not, then continuing calculation of parent-node Par (En) and sub-node Son (En) for
present entity En, algorithm goes back to step 2.

Step 6. Reacquire three sub-models of Top, Msm and Loc.

The same theory with Algorithm 1, the worst time complexity of algorithm 2 is caused by the
maximum amount (n) of entity En, the maximum traceable length of leaf node forward and the
maximum extensible length s downward, thus, record the algorithm complexity as O(n*(k+s)).

3. Architecture of Data Business for DIoT

In this section, the information model of power distribution IoT under business system structure is
raised, as the picture 1 shows. It divides the information model of power distribution IoT under
business system structure to three layers: layer of date model, layer of data component and layer of
data business. Layer of data mode is based on CIM model[6]. universal extension grid business is
processed firstly and then construct three sub-models of power distribution IoT as basement of
information model of power distribution IoT[7]. Layer of data components includes the technological
elements to support the whole chain of data collection, storage, calculation, management, which is
based on marketing business information, collection of electricity usage, customer service information,
automatic electricity distribution information and automatic dispatch information and others’ basic
data referred to power distribution IoT, that is considered as the core of technology in power
distribution IoT. Layer of data business contains lots of micro data services like, interrogation,
announcement of blackout, location based service and data collation, as well as provides data invoking
and data assembling service to various users[8].
Take the example from elements of data collation to describe the process of Algorithm model of even-triggered automatic collation. Detailed processes are shown in Picture 2. If there is inconsistent situation happening under information model of power distribution IoT, like report about blackout from number 10268732 of HPLC electricity meter. But as the topological calculation results shown, the rest HPLC electricity meters in the same transformer report the normal three-phase current and voltage data. Emergency crews find out that number 10268732 of HPLC electricity meter actually belong to another transformer after being spot according to map navigation, and they active data collation function through mobile terminal in order to correct data file of number 10268732 of HPLC electricity meter. After that topological sub-model of transformer is recalculated by system, if number 10268732 of HPLC electricity meter reports blackout again, there is no data collation demand and data inconsistency situation occurring. What is more, system can provide information about inconsistent devices in present location, based on data access authority of emergency crew after they arrive the spot. It also forms collative sheet to send to emergency crew in order to collate data according to practical device connection, as well as dismiss the rest quality problem within certain range in current location. For instant, emergency crew is able to collate the unexpected measurement data within 500 meters around the location of number 10268732 of HPLC electricity meter manually, it is a great way to save the time cost and labor cost efficiently.

**Figure 1.** Architecture of Data Business for DIoT.

**Figure 2.** Procedure of Data Collation.
4. Application
The research based on mobile energy internet, location sensitive data[9], GIS service[10] and an applicable example of power distribution IoT system is the fundamental step to explore the uniform information model of marketing business information, collection of electricity usage, customer service information, automatic electricity distribution information and automatic dispatch information after updating and conversing data. It supports to dispatch and command the distribution network, emergency maintenance, as well as the operation and maintenance of distribution network, program the distribution network. It also covers other fundamental application and satisfy the demand of “One Map of distribution grid”. Further, it could save the problems on incomplete, indirect reports about blackout of distribution network, including the difficulties on distributing emergency maintenance resource and commanding. various system interlacements like OMS, PMS and DMS, unexpected situation of devices and open-loop technological process. Project develops successfully up to now.

5. Final Statement and Further Challenge
This article raises information model of power distribution IoT based on research of development of energy internet and realistic business demand, it discusses the Logical Topology, matching of measurement value for measurement point and isomorphic model of map location and provides a model’s consistency algorithm. Further, it introduces the structure of connected data product of power distribution IoT and makes an analysis of its capacity. At last, introduce a successful research and development case of information model of Power Distribution IoT to prove practicability of it. Based on research done for the essay, following conclusions can be made: The questions about consistency of marketing and distribution model in practice can be abstracted to consistency of DIoT sub-model. Further tasks cover expressing sub-models by bigraph model[11] in power distribution IoT, constructing more complicated application model based on information model of power distribution IoT after testing it performance by extensive experiment.

6. References
[1] Sun Quuye, Teng Fei, Zhang Huaguang. Energy Internet and Its Key Control Issues [J]. 2017. Acta Automatica Sinica vol 43(2). pp 176-194.
[2] http://www.geidco.org/.
[3] Liu X , Liao Z , Chen J , et al. Architecture of A Mobile Energy Internet[J]. 2020. Iop Conference, 428:012003.
[4] Ullah I , Youn H Y . Intelligent Data Fusion for Smart IoT Environment: A Survey[J]. 2020. Wireless Personal Communications, vol 9.
[5] Mao YQ,Shen SB. Information Model and Capability Analysis of the Internet of Things[J]. 2014. Journal of Software vol 25(8). pp 1685-1695.
[6] V Tosic, S Dordevic. The Common Information Model (CIM) standard - an analysis of features and open issues[C]. 1999. International Conference on Telecommunications in Modern Satellite. IEEE Xplore.
[7] Yi-Song LI, Qi Y, Nan HU, et al. SG-CIM based Power Information System Monitoring Model[J]. 2012. Electric Power Information Technology.
[8] Paul Albrecht. Graphical visualization of data product using browser[J]. 2006.
[9] Xianming Liu, Li Pan. A Location-Based Data Product. 2016. Proceedings of 17th IEEE/ACIS International Conference on SPND. pp 243-248.
[10] Liu Xianming et al. Grid GIS Service Management System. China. ZL201310186784.7[P]. 2016-08-23.
[11] Robin Milner. Bigraphical Reactive Systems: Basic Theory[C]. 2001. International Conference of Mathematicians.