IMPACT ASSESSMENT CRITERIA OF DISTRIBUTION SYSTEM ARCHITECTURE

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ABSTRACT

The distribution system is experiencing rapid changes such as growth in low carbon technology connection and changes of customer needs. These changes bring challenges to the current system in maintaining an efficient and secure supply. Possible distribution system architectures for the future have been proposed to fulfil future requirements. Yet, it is still unclear which architecture will bring the maximum benefits to key stakeholders across the distribution system. This paper proposes simple and efficient criteria to evaluate possible future distribution system architectures. The proposed criteria take learnings from the Five Case Model and adapt them to assess the impact on key stakeholders. Adding the key stakeholders to the criteria helps the industry and the regulator to understand whether a transitional change would bring positive or negative impacts to each key stakeholder, and ultimately the system as a whole. The results of the impact assessment will assist the industry and the regulator to identify the most appropriate industrial structure that would create the best value for key stakeholders.

INTRODUCTION

With the development of low carbon technology, the total generation will increase from 103GW (2018) to 268GW by 2050 [1]. Up to 65% of the total generation could be distributed energy resources (DERs) that connecting to the edge of the distribution system [1]. The connection of these DERs, i.e., distributed generation, electric vehicles and advanced information and communication technology, brings benefits to customers but violates the distribution network. The current distribution system is not capable of accommodating a large amount of DERs while still ensuring a safe and efficient operating environment. As a result, a few research has published possible architectures for the future power system. The Future Power System Architecture Project indicates seven drivers and challenges of developing new functions of the power system [2, 3]. The Open Networks Project proposed five future worlds for power market based on the Smart Grid Architecture Models [4, 5]. The five new worlds identify DSO roles under different market mechanisms. Three possible architectures for the future distribution system were proposed in [6], it indicates that the distribution system is evolving in a decentralized way.

Impact assessment is a good way to assess the architectures and it has been carried out across various areas, especially in business and industry. Ofgem had published assessment criteria for Electricity System Operator (ESO) [7] for price control framework options. The price control framework mainly considers the outcomes that can be achieved by evolving to ESO. Report [8] established an impact assessment for different arrangements on balancing market within the European. National grid performed an economic analysis of 76 reinforcement options of the transmission network to find the optimal options for investment [9]. Nonetheless, none of these works gives an assessment criteria for the future distribution system architectures.

The Open Networks Project had published a draft assessment criteria for appraisal of distribution system architectures. This criteria follows the guidance of the Five Case Model and a short explanation is given to each sub-criteria. These criteria show the advantage of including customer experience, but leave out the impacts on other stakeholders.

Therefore, this paper proposes simple, systematic and precedence criteria for the industry and the regulator to evaluate all the possible architectures of future distribution system following the guidance is given by HM Treasury's Green Book [10]. The use of optimism bias is also advised by the Green Book. Optimism bias is to ensure that appraisers are not too optimistic about the key factors like costs and benefits. The optimism bias should be determined by historic data and appraisers' experiences. The proposed assessment criteria include four main dimensions. i.e., strategic, economic, commercial and management, to evaluate the impacts on key stakeholders (e.g. generator, customer, etc) under different system architectures. The proposed impact assessment criteria ensure that the new architecture will meet the changing requirements and create the best value for the key stakeholder to optimize the whole system.

THE FIVE CASE MODEL

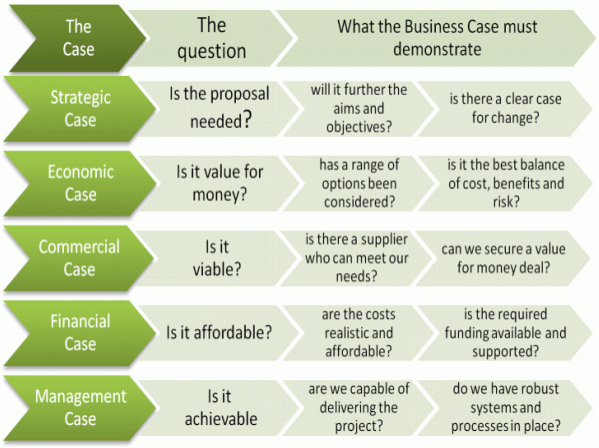
The model was first developed as a result of poor quality and inconsistently structured business cases for IT developments that went to Treasury for approval and funding [11]. It has evolved over time and has been widely adopted across the public sector and the majority of government departments as the gold standard for better business cases [11]. The five cases, as shown in Table I are strategic, economic, commercial, financial and management case [10].

1) The strategic case describes the case for change, including the rationale for intervention. In this

case, the question of whether changes are required should be answered. The strategic case should also identify how to bridge the gap between expected outcomes and Business As Usual (BAU).

2) The economic case represents the social value of intervention compared to continuing with BAU. The best balance of cost, benefit and risk to the public should be explained in detail.
3) The commercial case is the market viability, i.e., the procurement and commercial arrangements for implementing a proposal.
4) The financial case evaluates whether the proposal is affordable in terms of the total cost.

Table I. The five case model [12]



5) The management case demonstrates that a preferred option can be delivered successfully. The changing process of a structure requires large technical support. It is necessary to ensure that all the technical requirements are able to be met.

The Open Networks Project

The Open Networks Project proposed draft assessment criteria which follow the guidance of the Five Case Model and are used to assess the strength and weakness of the five potential future electricity networks (‘future worlds’) that had been proposed earlier [5].

1) The strategic case is to judge how well each possible model can address the two main changes: enhance customer experience and greater environmental sustainability. The customer experience includes choice, fairness, affordability and confidence and trust. This sub-criteria assess how well each World will provide a fair and transparent environment with affordable choices for the customers. The greater environmental sustainability stresses the facilitation of energy efficiency and de-carbonization. It sees how each World performs in increasing energy efficiency and reducing redundant losses by using closer generation. It also stresses that the facilitation of decarbonization in different areas, e.g., electricity, heat and transport.
2) The economic case is to analyze the efficiency of each model while changing. The economic case includes financial benefits and whole system optimization. The benefits of implementation and operation in terms of upfront investment and ongoing operational costs show how efficient each world is. The whole system optimization suggests that more flexibility should be brought into the system and optimizations can also be done locally. The future system is expected to be completed and, therefore, it is vital to managing conflicts between forecasted and actual operations. More importantly, the future system needs to ensure smooth coordination among all the participants. The economic case identifies how efficient each World is financially and technically.
3) The commercial case cares about the delivery of each model, i.e., market viability and regulation appropriateness. The power market needs new mechanisms and arrangements to be adapted to the changes in the architecture. At the same time, new regulations should be applied.
4) The financial case ensures the models have viable funding arrangements in terms of regulation and market. The future system needs to ensure funding for various purposes while necessary.
5) The management case exams the achievability of each model in terms of complexity. It includes industry structure and organization and technical performance. The industry structure and organization should work as a neutral market facilitator to deliver a transparent and fair market to the customers. The complexity of operating and implementing should be kept minimum for all the participants. Technical performance considers the safety, reliability and security of the network and its assets. Besides, resilience and recoverability are also tested to show how fast and accurate the World reacts to a fault.

The assessment criteria of Open Networks Project shows an advantage in using the Five Case Model to compare the advantages and disadvantages of the five Worlds. Moreover, the customer experience is also included in the criteria. The customer is becoming an important part in the future active distribution system so that more attention should be paid to satisfy the customer needs.

However, this criteria lacks explanations to help people understand the meaning of each case in the electricity system. Besides, the sub-criteria are

unsystematic and lack hierarchy. This 31 sub-criteria are too much into details which make this framework of unclear and difficult for industry and the regulator to use and evaluate the distribution system architectures. Furthermore, these criteria do not show the influences of each World to other stakeholders apart from customers. Changing to a new World means different for each stakeholder and there may be benefit conflicts between two stakeholders. Consequently, it is vital to know how the changes are affecting the stakeholders so that industry and the regulator can make optimal decisions on changing.

DEVELOPMENT OF ALTERNATIVE IMPACT ASSESSMENT CRITERIA

In this section, alternative impact assessment criteria are proposed and explained in detail. The proposed assessment criteria are composed of two factors: key stakeholders and four dimensions. The four dimensions adopted the Five Case Model and apply them to assess the impacts on the key stakeholders and ultimately the system as a whole. The proposed assessment criteria are given in Table II.

The four dimensions

The five case model is adapted into four dimensions for assessing the distribution system. The financial case merged into the economic dimension. To understand the other four dimensions, an explanation is given for each dimension.

1) The strategic dimension – sustainability and customer satisfaction: According to the government's call on evolving to a sustainable future, the future distribution system should be able to facilitate de-carbonization of electricity generation, heat and transport. Besides, the future distribution system needs an emphasis on using flexible resources and increasing energy efficiency. Another important call from the government is to satisfy the changing needs of various customers. In other words, the future distribution system should facilitate affordable, reliable, fair and transparent services for all customers.
2) The economic dimension – cost-effectiveness: The economic dimension represents the cost and benefits caused by the changes required by the strategic dimension. The implementation and operation of each change will bring benefits or costs to different parties. It is highly possible that the change benefits some stakeholders but influence the profits of other stakeholders. Because of the rapid change in the energy landscape, i.e., the behaviour of customer and the penetration of DERs, the distribution system faces various changes in the future. To ensure a cost-effective system, it is necessary to identify whether there will be benefits for the stakeholders.
3) The commercial dimension – market viability: Power market is an important part of the distribution system and it is getting more important because of the increase of active customer and DERs. The future distribution system should be able to facilitate a neutral, simple, fair and transparent market for all the participants. Traditional power market is mainly a central energy market with ancillary services to ensure network stable and secure. However, with the increase DERs, local energy market has

Table II. Impact assessment criteria

Four dimensions / Key stakeholders		Strategic dimension	Economic dimension	Commercial dimension	Management dimension
		Sustainability and customer satisfaction	Cost-effectiveness	Market viability	Flexibility
Government					
Generator	Central				
	Local				
TSO					
Retailer					
DNO/DSO					
Customer	Passive customer				
	Active customer				
Aggregator					

drawn large interests form the public. Consequently, the market operation becomes more complexed and challenging. Therefore, how to ensure a stable market environment is extremely vital for developing the future distribution system. Moreover, the distribution system should be adaptive to the possible changes in the future energy landscape.

4) The management dimension – flexibility: The management dimension is the technical requirements of changing to the new distribution system architecture. OVO energy published a flexibility first approach adopting advanced technologies such as artificial intelligence and energy storage to address future challenges [12]. The future distribution network needs to be safe and reliable for future customers, both active and passive. While adopting new technologies, physical implementation can become very complicated. Therefore, the future distribution system is expected to decrease the complexity of implementation. Besides, the distribution system should be able to provide space for new developments, such as DER connection and technology improvement.

The key stakeholders

To assess the impacts of the future distribution system, it is necessary to understand the impacts on the stakeholders. In the future distribution system, various types of stakeholders exist. Therefore, generally, only the key stakeholders are chosen instead of all. The rest of stakeholders can be included if necessary under certain circumstance. Here is the list of key stakeholders:

Government: The government publishes a policy to guide the developing of the energy system and protects the interests and rights of the customers.

Generator: Because of the developments of the technologies, the cost of DER has decreased dramatically in recent years and therefore a large growth in the number of local generators. Consequently, the central bulk generators are gradually replaced by local generators. Local generators are more flexible and environmental-friendly, however less reliable compared to central generators.

TSO: The increase of DERs drives the power system to evolve into a decentralized future. Traditional central transmission system will face new challenges and requirements.

Distribution Network Operators (DNOs) and future Distribution System Operators (DSOs): More local renewable resources, e.g., DG, EV and ES, are connecting to the distribution system. DNO and future DSO faces the challenge of maintaining system reliability and safety. It also should be noted that there be more opportunities for different market mechanisms in the future distribution system. As a result, the future DSOs should also be responsible for distribution market operation [13]. Besides, the coordination between market and network becomes more and more important. Future DSOs are also expected to act as coordinator.

Aggregator: Aggregator is the communicator between DSO and customer. To ensure demand is matched by generation in real-time, communication is a vital factor. The aggregators need to improve and adopt more advanced technologies for communication and information exchanging.

Retailer: The curtailment of central generation brings challenges to the retailers as well. Retailers need to build new business models that can accommodate both the central and local generation.

Customer: Traditionally, customers are passive consumers only purchase electricity from the retailers. With the development of technology, passive consumers are able to install DERs to supply their own demand and even sell the excess electricity to the others. As a result, customers become more active and there are willing to join in the electricity market to gain more profit. Hence, the customer for the future distribution system will be a combination of active and passive customers.

Application

Possible architectures can be assessed using the proposed criteria. It should be noted that one system architecture may not be able to meet requirements from all the stakeholders, i.e., only part of the stakeholders are satisfied with the changes in system architecture. The proposed impact assessment criteria can reflect influences on each key stakeholder under different dimension. Therefore, it helps the industry and the regulator to balance between the pros and cons of possible changes. Industry and the regulator can make optimal decisions to satisfy as many key stakeholders as possible with the help of the impact assessment results.

CONCLUSION

Alternative impact assessment criteria are proposed by taking learnings from the Five Case Model and the Open Networks Project and use them to assess the impacts on key stakeholders. The proposed assessment criteria have four main dimensions. The strategic dimension focuses on environmental sustainability and customer satisfaction. The economic dimension discusses the cost-effectiveness of the changes. The commercial dimension cares about the market viability of the new architecture. The management dimension answers whether is new architecture is flexible

enough for the industry and customers. The four dimensions are used to assess impacts on the key stakeholders. The influence of the stakeholders is the guideline for industry and the regulator to develop a new system architecture. The key stakeholders should include but not limit to the government, generation (central and local), TSO, DNO (or future DSO) and customer (active and passive). Other key stakeholders, such as retailer and aggregator, can be included depends on the requirements of different structures.

As it is difficult to find a perfect system architecture which satisfies all the key stakeholders, DNOs may need to choose the option that brings benefits to the majority of the key stakeholders. This framework presents a comprehensive result which helps the DNO to locate major benefits and make trade-offs. The proposed impact assessment criteria is a simple, efficient and easy way for new system architecture evaluation and give a clear result of the impact on each key stakeholder and eventually the system as a whole.

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