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Dimensions and Factors that Determine Integration of Small-Scale Sources in the Structures of Virtual Power Plants

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Abstract
In the paper the author has attempted to achieve two convergent objectives: cognitive and empirical ones. The cognitive goal constituted an analysis of the definitions of virtual organi-sations and their adaptation while defining Virtual Power Plants (VPPs). When discussing the discourse in the area of virtual organisations, the author has attempted to justify the fact that the terminology pertaining to virtual organisations should constitute the foundations for defining Virtual Power Plants. With such an assumption, a vital importance has been assigned to co-sharing of "soft" resources – key competencies, and also organisational (managerial) integration. In the context of the adopted definitions, the distributed structure of virtual power plant has been em-bedded into four layers of Smart Grid: Customer Technology, Operational Technology, Smart Metering, Energy Management System. A measurable value of the conducted discourse has been aggregation of management functions of VPP, carried out in the four-layer structure of Smart Grid. In turn, the empirical objective was to determine and distinguish, based on the conducted expert research, the factors that determine the development of small-scale energy sector, including re-newable energy sources and prosumer installations – simultaneously determining the inclination of distributed electricity producers to mutual integration in the structures of virtual power plants. Assuming, in accordance with the definitions and discourse included in the first part of the paper, that the determined factors, among others, creating virtual power plants are not only of techno-logical nature, the author has developed four portfolios of these factors. They include the following ones: technological, economic (including micro- and macro-economic), environmental, and social. The experts participating in the research could select 5 factors from each of the developed portfolio which in their opinion determined the inclination of distributed electricity producers to integrate their sources in the structures of virtual power plants. A measurable value of the empirical part has been aggregating the determinants generated and distinguished in the research process.

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1. Introduction

The concept of Virtual Organisations emerged in various areas of human activity accompanying the diffusion of Information and Communication Technologies. The literature on the subject is abundant in heterogeneous definitions of Virtual Organisations. With reference to the distinguished diffusion of ICT technologies, Virtual Organisations constitute a network integration of autonomous firms, concentrated in chains of vertical and horizontal links – with the use of computer networks resources, including the possibility to utilise information banks and knowledge incubators. This is also an organisational network – a set of integrated entities in the virtual management environment (Owoc and Sitarska, 2008). When discussing the issue of a virtual organisation in a purely subjective grasp, it should also be indicated that it also means inclusion of all or only selected persons from various organisations, and also economic entities, non-profit entities into a common market game (Kuceba et al., 2018; Kisielnicki, 2008). Obviously, it should be stressed that this is an organisation of a variable organisational structure – the structure that can be flexibly adjusted to the needs of the demand side (final customers). Organisational structure is created based on a division of resources and collaboration within Virtual Organisation is temporary. It structure is subject to continual changes, is dynamic, and progressive (Kuceba, 2011). It is adjusted in an optimal manner to capacities of its individual entities, as well as the needs of final customers. The virtual structure facilitates adjustment of organisation's size and its products depending on the market needs, and simultaneously it reinforces final customer satisfaction. It should also be indicted that owing to the lack of unequivocal legal regulations pertaining to collaboration of distributed energy producers a vital factor is mutual trust. On the markets characterised by strong competition of large-scale entities, micro- and small- economic entities can act as large, integrated enterprises. In the discourse on Virtual Organisations of economic nature these organisations are recognised as the foundation for defining Virtual Power Plants, and this has also been the case in the present paper.

2. Taxonomy of Virtual Power Plants (VPPs)

In the economic practice the proposed in the introduction form of Virtual Organisa-tions is currently being rendered and it shows prospects of intense escalation on electricity markets, analysed in the subjective grasp (Kasaei et al., 2017). Presently, the concentration on electricity market pertains to a small number of large economic entities – energy corporations (stimulation of weak competition). Introduction of VPPs will enable new, especially local, entities that utilise renewable and alternative sources (frequently also prosumers of RES electricity) in the production of electricity, to introduce to the market accumulated elec-tricity in a flexible virtual organisational structure, being already competition for the corporate energy sector. On the basis of the introduced definitions of Virtual Organisa-tions, Virtual Power Plants are mutually related sources of distributed generation, in particular small scale renewable energy sources, including prosumer installations, with the use of teleinformatic networks resources and technical resources (Kuceba, 2011; Dorothy and Sasilatha, 2017). Virtual Power Plant in the technical and informatic grasp is also a concentration of distributed genera-tion, RES micro-installations in one logically interconnected system, in which energy sources are installed close to final customers (frequently prosumers) (Qarabsh et al., 2020). Virtual Power Plants are a combination of various small sources/producers of electricity, not only with the use of electro-energy networks. They are also integrated in a virtual organisational network (frequently business one). In the network they will operate and collaborate cre-ating a large-scale distributed power plant. The plant can be controlled, for instance, through a local Decentralized Energy Management System (DEMS). Virtual Power Plant, understood also as an organisational network, combines in its structure key competencies (including the unique knowledge on its own capacity and actual energy demand) of individual dispersed producers of electricity in small-scale local sources (institutional nature) (Kuceba, 2011; Deng et al., 2015). Their virtual operation and collaboration is focused on carrying out inte-grated competencies of particular entities (functional nature) (Kuceba, 2011; Deng et al., 2015). In accordance with the presented in the Introduction concept of Virtual Organisations, Virtual Power Plant is an organisational network of entities, which is created based on the principle of voluntary participation in its structure, devoid of time, subjective and subject constraints.

Virtual Power Plant is also identified as a space that integrates innovative technolo-gies of dispersed generation, renewable energy sources, or prosumer installations. In the spatial grasp – scientific and ontological one, Virtual Power Plant has a modular struc-ture, which imitates the structure of a real object. Such a structure is based on the fast-prototyping concept – a possibility to configure any spatial combinations of real and modelled elements. Virtual Power Plants are also defined by technical scientific circles and experts in the investigated area as unlimited number of distributed small local power plants or combined heat and power plants utilising primarily RES, which confirms their local nature (Popczyk, 2011). Apart from RES, experts also indicate the chances of local utilisation of non-system gas or return to shale gas (using new, highly-advanced, low-energy tech-nologies of mining and exploitation). Particular electricity sources on the side of local producers create virtual structures of a multi-block power plant. They are interconnected technologically, functionally, and logically in Smart Grids (justification in the further part of the paper) (Andreadou et al., 2016). They can also operate within these networks as maintenance free ones. They are managed through the internet or intranet. This also where their virtuality comes from. The growing interest in the integration of local electricity producers in the area of co-sharing resources and products in the virtual structure is closely correlated with the increased capacity of Virtual Power Plants. This comes from the summarised capacities of distributed generation sources, renewable sources, and also prosumer installations. Simultaneously, this growth stimulates improvement/increase of local energy security through diversification of sources, and also through independence of prosumers, local communities, from supplies of system electricity. To sum up this taxonomical part, Vir-tual Power Plants in contrast with the terminology functioning in the area of technical sciences, are not only limited to co-sharing of technological resources of individual elec-tricity producers in small-scale sources. Equally vital importance is attributed to co-sharing of "soft" resources – key competencies, among others knowledge of the actual capacity of individual distributed electricity producers and their knowledge of the actual local daily demand for electricity (Owoc and Sitarska, 2008; Kuceba, 2011).

3. Structure of VPP Embedded into Layers of Smart Grid

With reference to the first definition introduced in the present paper, which is simultaneously the initial definition of the discussion concentrated around terminology, it has been assumed that Virtual Power Plants *are mutually interconnected sources of dispersed generation, small-scale renewable energy sources in particular, including prosumer installations, with the use of resources of teleinformatic networks and tech-*

nical resources. In reality the technical, technological, functional, logical, and first of all organisational (managerial), when defining Virtual Power Plant as an economic entity, is possible in Smart Grids (Kuceba, 2011; Andreadou et al., 2016; Rihan, 2019). While referring to previous publications, among others of this paper's author, Smart Grids are assigned functions of physical, logical, and also organisational or even managerial integrators. This is reflected in subsequent layers in which the distributed structure of Virtual Power Plant is embedded. Referring to part of the abovementioned definition of Virtual Power Plant „*(...) mutual interconnections of distributed generation sources, small-scale renewable energy sources in particular (...)*", in the context of Smart Grid layers, this is carried out in two physical layers, created by: 1) distribute and dispersed energy sources, small-scale RES, prosumer installations, distributed energy receivers, control devices, automatic regulation, safety automatics (Layer 1 Customer Technology – CT) and 2) electricity distribution networks – physical integrators (Layer 2 Operational Technology).

In the first layer of Smart Grid one can find positioned sources of local electricity producers: distributed generation, small-scale RES, without neglecting the possibility to allocate in this layer prosumer micro-installations. In particular, indicating simultaneously empowered objects of Virtual Power Plant, the following can be allocated in the first layer of Smart Grid (Kuceba et al., 2018):

- CHP/RES energy sources (e.g. small-scale sources, consisting of: micro- and mini dispersed gas generation powered for example from micro-biogas plants, mini wind turbines, photovoltaic and photothermal cells; fuel cells, heat pumps, energy recovery technologies).
- Energy reservoirs, including hybrid electric vehicles (PHEV).
- Micro-network securing and controlling systems.
- Intelligent appliances and electricity receivers - remotely controlled electricity receivers; systems of intelligent electric vehicles charging: plug-in hybrid electric vehicle (PHEV), plug-in hybrid vehicle (PHV).

The second layer of Smart Grid - Operational Technology – OT, also a physical one, where occur „*(...) mutual interconnections of sources (...)*" VPP is created by physical network integration of technologies implemented in the first layer. The second layer includes in particular: energy micro-networks - decentralized low-voltage micro-networks, heating micro-networks and decentralized gas micro-networks. Second layer is the platform of physical integration of local energy producers (electricity, heat, bio-gas, hydrogen, co-generation and polygeneration energy, among others: CHP heat and power plants, Renewable Energy Sources, micro- and mini-sources of highly-efficient cogeneration) with final consumers as well as prosumers, for instance local governments, local businesses, housing associations and condominiums, individual consumers.

Next two layers of Smart Grid are responsible for integration „*(...) interconnections (...)*" – functional. logical, and what has been stressed in the paper, organisational and managerial interconnections of VPP. These layers with the embedded VPP structure are: the third layer – Smart Metering, and layer four – Energy Management Systems (EMS). In particular, the third layer Smart Metering (SM), consisting of Intelligent Metering Systems (Smart meters) and systems of Advanced Metering Infrastructure - AMI. In the AMI application environment measuring data is the source of information and knowledge on final customers. These are intelligent measuring systems consisting of the operational and analytic part. The operational part constitute complex tele-metering devices which allow to measure the demand for various types of produced and used energy in real time. The Advanced Metering Infrastructure (AMI) is an element of the Intelligent Metering System. It enables real time transmission of intelligent meters' readings to the server - temporary electricity use by final customers. The AMI is also a bridge integrating the user with the network operator, at the same time ensuring bidirectional communication.

The fourth layer of Smart Grid is a platform of logical and process integration of technologies implemented in the Customer Technology layer. This is a virtual management environment - the proposed decentralized intelligent infrastructure. The virtual environment of logical and process integration is created by: computer networks (e.g. Wi-Fi/WIMAX network, including protection of the intelligent grid), applications managing the dispersed infrastructure of dispersed energy technologies (energy sources, network appliances and consumer electricity receivers); Energy Management Systems (EMS), including DEMS (Decentralized Energy Management Systems) and Supervisory Control and Data Acquisition Systems (SCADA) (Kuceba, 2011).

VPP embedded into the four-layer structure of Smart Grid can also be evaluated in two dimensions: creating energy value in virtual structures and managing electricity generated in the "interconnected" distributed energy sources, small-scale RES, and prosumer installations. Individual links of value creation are subsequent layers of Smart Grid, which include the embedded VPP (Kuceba et al., 2018). In the first layer – Operational Technology, which are: generation and consumption of electricity, which is justified by the prosumption of electricity taking place in Smart Grids. It needs to be stressed the in the traditional electro-energy systems these two processes are separated by the processes such as transmission of electricity and its distribution. Referring to creation of energy value in Smart Grid networks the second process in the second layer is simultaneous physical integration of distributed and dispersed sources of electricity and distributed infrastructure of electricity receivers on the side of final customers. The integration undergoing in electro-energy networks (frequently at medium or low voltage). Aggregation of the demand for electricity of final customers and balancing this demand with energy generated in distributed and dispersed energy sources is another process in creating the value of electricity taking place in the third layer – Smart Metering. According to the justified above qualities of Smart Grids it is possible through development of smart measurement infrastructure (Smart Meters). The last process of creating the energy value taking place in layer four (in Energy Management Systems) is the analysis of availability and demand in VPP structure a measurable effect of which is creating work schedules, plans of managing the distributed and dispersed infrastructure of VPP on the supply side (generation) and demand side (consumption). Created in layer four schedules and plans of energy management in VPP structure are the foundations of carrying out subsequent management functions. In the fourth layer, in the context of energy management, the first function of management is carried out based on the generated schedules – planning, carried out by Energy Management Systems. Another function of management, controlling, is carried out in the third layer. The result of control is total balancing of demand and supply. If surpluses of energy occur in VPP structure balancing is associated with introduction of electricity into the distribution electro-energy network. If shortages of energy occur, in the third layer, the control function ensures balancing of the demand for electricity from the distribution networks that belong to the DSO. A vital function of energy management that is unique for Smart Grids is decision-making separation, in the context of balancing the elementary demand and supply of energy on the side of distributed in this network producers and final customers. The separation occurs in the physical layer of Smart Grids (the second layer). Also, the separation in the second layer, in the context of energy management, is in inversion with the integration taking place also in the second layer, but in the context of value creation. Implementation of decisions on the side of electricity producers in distributed and dispersed sources and final customers occurs directly in the operational layer – the first layer. Thus, a unique quality and distinguishing feature in VPP structure is the undergoing inversion, opposite directions between subsequent processes of energy creation and functions of energy management. However, the mutual connections between value creation and other management functions create a closed circuit, which ensures and simultaneously justifies another unique feature of VPP structure – flexibility of generation in the context of actual, dynamically changing demand for electricity. The connections in the closed circuit between energy value creation and its management have been presented in Figure 1. Particular layers of Smart Grids reflect subsequent management levels of VPP that occur in organisational structures of archetypal organisations (Kuceba et al., 2018; Kuceba, 2011).

Smart Grids, where the allocation of VPP's resources occurs, are also analysed from the perspective of their utility, starting with the final customer/consumer. To strengthen the position of customers they are introduced new roles, apart from using/consuming energy. Such a role is generating energy in distributed energy sources, especially in micro-RES. This has exacted bidirectional flows of energy, and so the necessity to apply bidirectional readings in Smart Meters. To automate the management of distributed resources (DR) operation, including distributed energy receivers, in the third layer (Figure 1), consumers and energy providers can make use of Automatic Decision Support Systems (Kuceba et al., 2018). These systems are responsible for controlling the technical infrastructure of VPP, frequently based on inference-explanatory modules. Presently, full automation is also possible thanks to the Internet of Things (IoT) (Bakar et al., 2019), which offers remote control over the distributed technical infrastructure of Smart Grid.

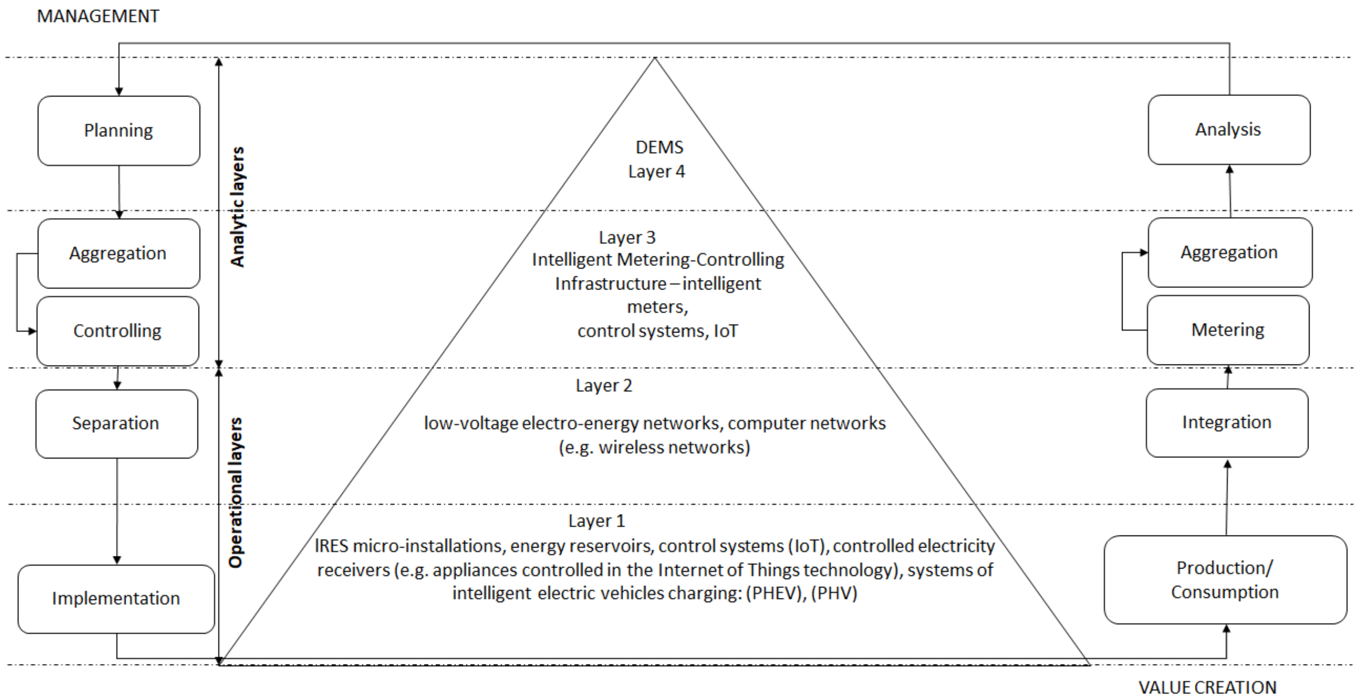

Fig. 1. Management functions of VPP, carried out in the four-layer structure of Smart Grids.

The technical and technological aspects of VPP are the ones that are most frequently analysed and discussed in the literature on the subject. Therefore, in the final part of the paper the cognitive focus is on determinants of allocating distributed energy resources in the virtual organisational structure by investors, local energy producers, and electricity prosumers.

4. Key Determinants of Local Virtual Power Plants

The empirical objective of the presentation included in the present paper is to identify and distinguish factors determining the development of small-scale energy sector, including renewable energy sources, and simultaneously determining the propensity of distributed producers to integrate into virtual power plant structures. This has been based on the cognitive studies that covered: existing periodicals, existing literature, legislative documents (Kuceba, 2011; Popczyk, 2011; A European Green Deal, 2021; The RES tool, 2021; EPRS-BRI, 2021; Nowelizacja ustawy o OZE..., 2021; EU Market Outlook for Solar Power 2020-2024, 2021; Raport IEO Rynek Fotowoltaiki w Polsce 2020, 2021; Niedziolka, 2018) and own observations within the supervisory board of an energy company. The company's profile of operation includes among other investments in the field of photovoltaic farms. On this basis factors were determined that may affect not only the development of small-scale energy sector, but also the inclination of electricity producers in these sources to create virtual structures in order to increase the total supply of electricity produced. This in turn increases their position, potential and often competitive advantage. Assuming, in accordance with the definitions and discourse in the first part of the paper, that the determined factors, including creating virtual power plants, are not only of technological nature, four portfolios of these factors have been created: technological, economic (including micro- and macro-economic), environmental and social ones. The creation of these four portfolios of development factors of small-scale energy sector and Virtual Power Plants is also the justification that their activities fall within the scope of economic activity perceived in the dimensions of sustainable development (Lee et al., 2017; Koszarek-Cyra, 2016). Distinguishing four portfolios determining the development of small-scale energy sector and their integration in virtual structures made it possible to develop a survey questionnaire, one part of which concerned factors stimulating the integration of the selected sources in a virtual environment (in the structures of the Virtual Power Plant). The factors listed in the questionnaire were subject to the process of selection by experts from the Supervisory Board of an energy company active, among others, in investments in the field of photovoltaic farms and experts collaborating with the author of the present paper. Experts participating in the study had the opportunity to choose 5 factors, from each created portfolio, that, in their opinion, determine or have the greatest impact on the propensity of distributed energy producers to integrate their electricity sources into virtual power plants structures. The present paper presents the already analysed factors that, based on the research, can be described as determinants of the development of virtual power plants. In technological, environmental, and social terms, 5 determinants were aggregated, while in the economic portfolio, due to the adopted division, 5 macroeconomic and 5 microeconomic determinants were distinguished. When selecting determinants from the group of assessed factors in individual portfolios, a quantitative criterion for the selection of determinants stimulating the integration of the selected small-scale sources in a virtual environment was adopted, - 5 factors with the highest indications, with the assumed necessary condition - MIN 75%, indications of the experts participating in the study. Table 1 summarises the distinguished determinants divided into categories according to the portfolios of factors included in the questionnaire: technological, economic (including micro- and macro-economic), environmental and social ones.

Table 1. Determinants of integration of small-scale sources, including RES and prosumer installations in the structure of the VPP distinguished in the research process.

Determinant category		**Determinant of integrating small-scale sources, including RES and prosumer installations in the VPP structure**
Economic	**Macro-**	1) Increased utilisation of renewable energy sources (RES) in the balance of energy raw resources, including biofuels, which reduces or eliminates contractual penalties for greenhouse gases emission on the EU ETS market 2) Stimulation and monitoring, in a virtual environment, development of competition mechanisms as the main means to rationalize unit energy prices; 3) Stimulation of investments and acceleration of growth of economic entities generating energy from small-scale sources, including RES in the local perspective 4) Financial support with the use of EU funds and environmental protection funds, including funds from substitution fees and penalties resulting from the obligatory participation of RES in production or consumption 5) Growth of GDP through investments in technological innovations of distributed generation, including RES micro-installations as well as prosumer ones
	Micro-	1) Orientation on the final customer of electricity / prosumer so as to increase loyalty and trust towards a new electricity producer, manage customer relations and continue research on customer needs and preferences 2) Increased tolerance in the aspect of uncertainty and changes resulting from non-linearity of the daily capacity of individual renewable energy sources (e.g. photovoltaics in a hybrid with heat pumps and micro-wind turbines)

		3) Stimulating small entrepreneurship on the energy market in a local perspective through network integration with their environment in the virtual environment of smart grids 4) Shortening delivery routes for final recipients and their optimal and dynamic adjustment in order to minimize energy-intensity and capital-intensity 5) Minimisation of management levels in VPP, in the Smart Grid management hierarchy
Technological		1) Increased energy efficiency of integrated non-linear RES energy sources in virtual structures of the VPP 2) Development and growth of distributed generation sources in the Energy System, including RES micro-installations and prosumer installations which use local energy potential 3) The use of energy hybrids, including the use of RES 4) Development of backup power sources so as to increase the reliability of supplies and use of final energy 5) Optimising the network operation and the manner of using the Smart Grid network infrastructure (e.g. reducing losses)
Environmental		1) Changing the structure of energy generation towards low-emission technologies and increasing the importance of RES directly on the side of final consumers/prosumers 2) Local counteracting low emissions 3) Increased ecological awareness by activating final customers not only to consume electricity but also to cooperate in the structures of the VPP 4) Joint undertakings of local communities regarding green activity 5) VPP as good practices in green marketing
Social		1) Social acceptance of infrastructural changes in the area of energy generation and energy transmission 2) Increased social affiliation within the structures of the VPP 3) Increased propensity to invest in small-scale RES 4) Increased energy savings at final users by using energy-saving receivers in an energy-saving environment 5) Integration of local housing communities

It needs to be indicated here, directly below the summary, that despite their differentiation the distinguished in the research process integration determinants of small-scale sources, including RES and prosumer installations, interpermeate.

5. Discussion of Results

While analysing the profile of VPP's development determinants in particular categories corresponding to the portfolios that include all the selectable factors – in the macroeconomic aspect, the experts perceive considerable chances of percentage increase in the balance of energy raw resources of RES, including biofuels, resulting from the integration of small-scale sources in the virtual environment. The experts also perceive that significant energy growths in VPP's structure, among others from small-scale RES of prosumer installation, translate into reduction or elimination of contractual penalties for greenhouse gases emission on the EU ETS market. In the case of the EU countries where these penalties are high, reduced emission of greenhouse gases will definitely be reflected in the constituent of generation cost in prices of electricity for final customers. It needs to be mentioned that penalties for excessive emission of greenhouse gases are eventually covered by energy consumers. In the macroeconomic grasp, the experts also perceive chances in integrating non-linear energy sources, especially RES, in the scope of flattening the resultant calendar characteristics of VPP's daily capacity and balancing the supply of electricity and the actual needs of volatile daily demand on the side of final customers. A vital macroeconomic determinant perceived by the experts is the development prospect of micro- and small-entrepreneurship pertaining to electricity production by distributed producers. The experts believe that the integration of distributed electricity producers in the structures of VPP can increase security and stability. This also means a growth of new investments, which given a considerable diffusion of small-scale electricity sources can translate into GDP growth at the local and regional level.

In the group of microeconomic determinant the experts distinguished primarily these factors that directly pertain to orientation on final customers of electricity or prosumers. They point to significant reduction of the "path" between energy producers and consumers, which conduces to management of mutual reactions, minimising losses, reduction of prices, and also reduced uncertainty resulting from the continuity of daily energy supplies coming from non-linear RES sources. At the microeconomic level the experts also perceive chances for the development of a new segment of small entrepreneurship on the electricity market, through a network integration in the virtual environment of Smart Grids. In commercialising such an activity another determinant has also been distinguished, namely reduced management levels of VPP, embedded into particular layers of Smart Grid.

In the group of factors located in the technological portfolio that determines inclination of distributed producers to integrate in the structures of virtual power plants, the following determinant of VPP has been distinguished: increased number of distributed generation sources in the Energy System, including RES micro-installations and prosumer installations, which utilise local energy potential. Another determinant according to the experts, which has been stressed in the context of energy security (defined as the state of covering the current and prospective demand for fuels and energy in an ecologically and economically justified manner, simultaneously being fully accepted by the society (Kuceba, 2011; Popczyk, 2011; Niedziolka, 2018)), is a potential diffusion, especially in local energy systems, of reserve energy sources, independent from centralised large-scale energy blocks. A considerable level of significance is also attributed by the experts, in the technological grasp, to optimisation of network's operation and the manner of utilising the infrastructure of Smart Grid, ensuring daily continuity of capacity. The integration of the distributed generation, small-scale RES, prosumer installations, is also perceived in the environmental dimension. In particular, the largest number of the experts' indications was assigned to the determinant related to reduction or even elimination of smog/low emission. The experts believe that activating final customers not to just consume electricity but also collaborate in the structures of VPP positively influences the growth of ecological awareness, and also the inclination to make investments in this area. This simultaneously permeates with the determinant indicated in the social dimension. In the social dimension the experts stress the importance of full social acceptance, and also the influence of integration of distributed energy producers on the integration of local commonholds.

6. Conclusions

In conclusion, in the present paper its author has attempted to empower virtual power plants, emphasizing the fact that empowered VPPs reflect the structure of a conventional power plant, which consists of autonomous energy blocks – generating units centrally disposed. Virtual activity and collaboration within VPP is focused on carrying out competencies of individual distributed producers of electricity, and the empowered organisation itself is created based on the principle of voluntary participation in its structure, and which is stressed devoid of time, spatial, subjective, and subject constraints. The author has indicated and attempted to justify that the inclination to co-create frequently temporary virtual structures does not depend exclusively on technological determinants. Equally important are also the determinants that justify such virtual entities in economic and environmental respect, simultaneously being fully accepted by the society.

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确定虚拟电厂结构中小规模源集成的维度和因素

關鍵詞
虚拟组织术语
虚拟电厂术语
智能电网层
虚拟电厂的决定因素

摘要
在这篇论文中，作者试图实现两个趋同的目标：认知目标和经验目标。认知目标构成了对虚拟组织的定义及其在定义虚拟发电厂（VPP）时的适应性的分析。在讨论虚拟组织领域的论述时，作者试图证明与虚拟组织相关的术语应该构成定义虚拟电厂的基础这一事实。在这样的假设下，“软”资源的共同共享——关键能力，以及组织（管理）整合——被赋予了至关重要的意义。在采用定义的背景下，虚拟电厂的分布式结构被嵌入到智能电网的四个层次中：客户技术、运营技术、智能计量、能源管理系统。所进行讨论的一个可衡量的价值是 VPP 管理功能的聚合，在智能电网的四层结构中进行。反过来，实证目标是根据进行的专家研究确定和区分决定小型能源部门发展的因素，包括可再生能源和产消者装置——同时确定分布式能源的倾向电力生产商在虚拟电厂结构中相互整合。假设根据本文第一部分中包含的定义和论述，创建虚拟发电厂等确定因素不仅具有技术性质，作者开发了这些因素的四个组合。它们包括以下方面：技术、经济（包括微观和宏观经济）、环境和社会。参与研究的专家可以从每个已开发的投资组合中选择 5 个因素，他们认为这些因素决定了分布式电力生产商将其资源整合到虚拟电厂结构中的倾向。经验部分的一个可衡量的价值是汇总研究过程中产生和区分的决定因素