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I4.0 Readiness Index in Electric Power Distribution in Serving Modern Consumers

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Abstract. Nowadays, the needs of modern human life are inseparable from the use of electrical energy. The development of eco-friendly technology continues to emerge rapidly to help facilitate daily life, such as electric vehicles (EV), electric stoves, and other modern equipment. A variety of modern equipment will have a technical impact on the distribution of electric power. Perusahaan Listrik Negara (PLN) is a state-own company, as one of the electricity service providers, must serve consumers reliably and efficiently. The existence of modern loads on the consumers side must be addressed with modern electricity supply, such as the preparation of smart grid technology, communication technology between EV charging stations, disturbance management, and efficient asset management. All of that is a readiness index for PLN to serve modern consumers. PLN needs to prepare technology and knowledge in the transformation of industry 4.0. This research helps PLN to assess the readiness of industry 4.0, which we call INDIST 4.0 (Power distribution readiness Index I4.0). The results of this study contain 5 Pillars, 15 Fields as a reference. Assessment for all distribution work areas in Indonesia with a value of 1.9 out of 4, meaning PLN is a newcomer and learner.

INTRODUCTION

Energy transformation is known as 3D, namely: decarbonisation, decentralisation, and digitalisation. These three things encourage the importance of using technology such as artificial intelligence and big data [1]. The increasing number of electricity consumers in Indonesia with various devices that absorb electrical energy such as electric vehicles, electric stoves, LED technology, and other modern equipment requires Perusahaan Listrik Negara (PLN) must provide reliable and efficient electricity. In supporting the decarbonisation program, PLN provides electricity to isolated areas outside Java-Bali such as Papua, Kalimantan, and Nusa Tenggara. For the decentralisation program, PLN creates the smart grid configuration to gain efficiency. While the digitalisation program, PLN can perform real-time billing models, consumer complaint management, and integration of electric charging stations to use the remaining vouchers for each electricity charging station efficiently. PLN must be ready to use and invest in industrial technology 4.0.

Industry 4.0, famously referred to as the I4.0 [2], is a strategic initiative introduced by the German government in 2011 at the Hannover Fair. This initiative aims to transform companies through digitalisation and the use of information technology and communication. I4.0 concept is the integration of cyber-physical systems and the Internet of things. I4.0 aims to increase productivity, respond to markets faster, and compete globally. Currently, the analysis of the study on the implementation of the I4.0 readiness index is limited to the manufacturing industry, particularly in the electronics, automotive, textile, food & beverage, and chemical industries. A comprehensive analysis of the readiness of the electricity sector has not yet been carried out, especially in Indonesia. In this paper, we develop measurement models and instruments. Our state-of-the-art research is shown in Table 1. It describes some of the I4.0 readiness

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indexes in some countries and explains the readiness index purpose. Several studies state that this measurement is related to the success in adopting new technology [3].

Figure 1. shows the research framework. The phenomenon of the emergence of modern electricity consumers is in line with policies in several countries, including Indonesia, regarding the energy transition to the use of carbon-based fossil energy, where fossil energy whose emissions produce CO2, also undergoes a transition towards decarbonisation or carbon emissions are lost [4, 5]. Part of the solution is to replace the trend of gasoline vehicles becomes electric vehicles, and gas stoves become electric stoves. The government also encourages electricity utilisation per capita in 2025 at 2,500 kWh/capita and in 2050 at 7,000 kWh/capita [6]. In addition, a new term appears, the consumer becomes prosumer. Prosumer is a combination of producer and consumer. Currently, PLN consumers are not only connoisseurs of electricity but can also produce electricity and sell it to PLN. From some of the phenomena mentioned above, PLN must transform. The transformation carried out requires a baseline and can be obtained from the readiness to transform to I4.0.

TABLE 1. State of the art

	Existing	**Our Purpose**
Research of Readiness Index I4.0	There are several measurement models related to industry 4.0, including ACATECH, PWC, IMPULS, SIRI, and INDI 4.0, But They are limited to the manufactured sector	New Model I4.0 Measurement for energy sector especially in Power Distribution (Not Manufactured)
The Reason Why Measuring I4.0 is Important	- As reference standards to measure the level of readiness of companies to transform into the industrial era 4.0 [4]	- As reference standards to measure the level of readiness I4.0 of Power Utility Company in Distribution to transform into the industry 4.0 - Help PLN to prepare technology and knowledge in the transformation of industry 4.0 in serving modern consumers

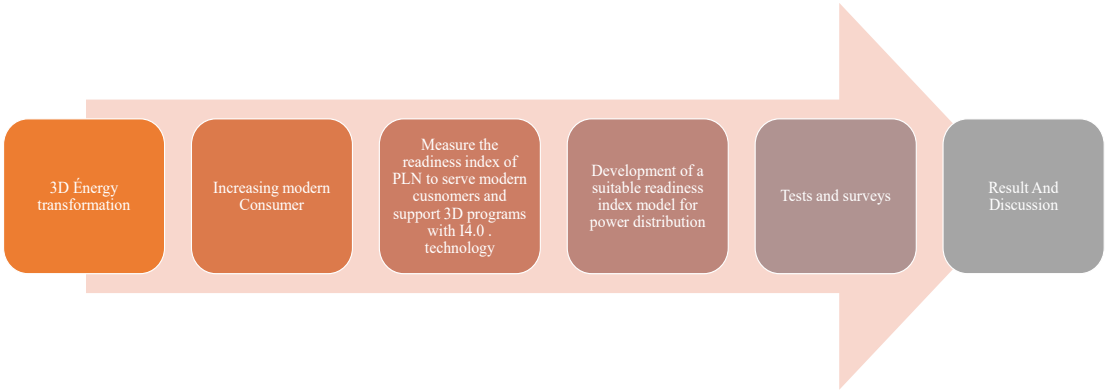


FIGURE 1. Research framework

The electricity sector is an essential part of modern life and important to promote economic growth in Indonesia. People use electricity for lighting, heating, cooling, cooking, operating appliances, computers, electronics, machinery, and charge the electric vehicle. Total Indonesia electricity consumption in 2020 was about 243 TWh [7] and two times greater in the last ten years. PLN serves 79 million consumers spanning a distribution network of almost 1 million KMS. Electricity is generated at power plants and moves through a complex network or grid of an electricity substation, power lines, and distribution transformers before it reaches consumers. That is why PLN needs to measure its readiness in using I4.0 technology.

I4.0 TECHNOLOGY

The term I4.0 aims to improve the efficiency of processes, routines, and systems [8]. I4.0 also provides benefits for companies to transform from conventional methods to digital, in which there is automation and the achievement of new business models [9]. From the existing literature, there are several explanations of technology in I4.0

[9,10,11,12,13]. There are four elements of I4.0 [8] technology which can be seen in Fig. 2. The approach to the four elements can be used as an indicator of readiness for implementation of I4.0 conducted by the Acatech Study. The details of I4.0 technology are described by PWC [14]. There are eleven technologies in I4.0 that can be seen in Table 2. Among others is technology need in power distribution, like mobile devices and location detection, because power distribution asset is distributed in the field.

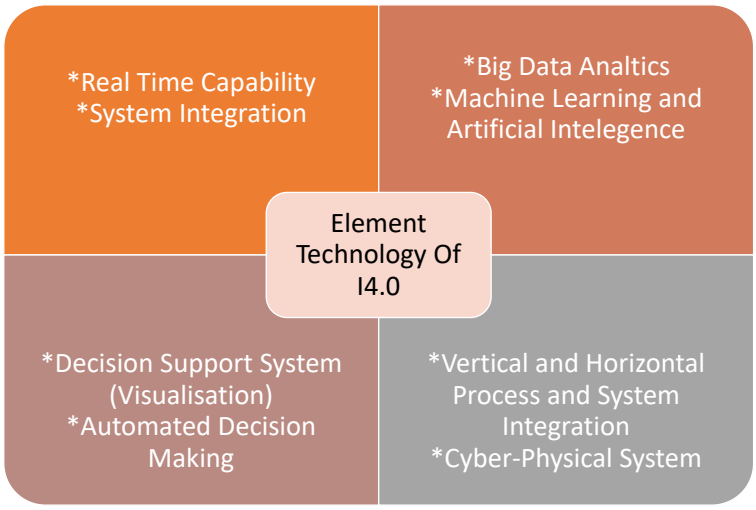


FIGURE 2. Element of Industry 4.0

TABLE 2. List of technology I4.0

No	Element	Technology
1	Digitalization and integration of vertical and horizontal value chains	Cloud Computing Mobile Devices IoT Platforms
2	Digitalization of product and service offering	Augmented reality Multilevel customer interaction and customer profiling Big data analytics and advanced algorithms
3	Digital business models and customer access	Location detection technologies Advanced human-machine interfaces Authentication & fraud detection 3D printing

METHODS

The methodology of this research is a systematic review. Collect various sources of measurement index I4.0. Examining the variables that are suitable to be applied in energy company. To measure the readiness index I4.0 is compiled in several aspects or known as pillars. Each measuring instrument adopts several pillars, such as ACATECH from Germany, IMPULS from Russia, and SIRI from Singapore. Pillar is a measurement variable. All of these pillars are described in Table 3.

Table 3. explains the pillars on the readiness index I4.0 that exist in several countries. Then they are divided into two groups. The pillars are arranged in Table 4. Furthermore, they are made in outline, namely pillars related to technology and those unrelated to technology. The value of unrelated to technology is 28% and related to technology is 72%.

From the list of pillars in Table 4. We can choose the pillars that are often mentioned when measuring the readiness index, namely:

Unrelated to technology:

1. Management & Organisation
2. People & Culture.

Related to Technology:

1. Technology I4.0
2. Digitalisation
3. Connectivity (Vertical/horizontal integration)

In the Acatech study that I4.0 is not only focused on technology. Companies also need to change their organisational structure and culture. The ultimate goal is to be a learning and agile company that can adapt continuously and agilely to a changing environment [18].

APPLICATIONS OF POWER DISTRIBUTION, TECHNOLOGY, AND DIGITALISATION

The electric power distribution system that reaches our homes consists of three parts, namely Generation (Power Plant), Transmission (Transmission), and Distribution (Distribution), as shown in Fig. 3. (a) Electricity begins to be generated at the generating centre. Then, step-up transformers increase the voltage to be carried using transmission lines over long distances. At one point, it is lowered to low voltage using a step-down transformer to be distributed to homes using distribution lines.

In the long process of electric power distribution, it must be reliable, efficient, and resilient. There is a technology that should be installed with consideration of the cost-benefit ratio. There is the entire process of distributing electricity in the generation, transmission, and distribution. Figure 3. (b) details the activities in the power distribution, including real-time sensing, voltage optimisation, transformer health monitoring, fault detection, and outage detection, and asset management [21]. These activities can be indicators of readiness for I4.0.

The technological process can also be adapted to the IEC 61986 standard. Digitalisation is part of the I4.0 transformation process. One of the library sources is IEC. IEC 61968 explains DMS (Distribution Management System) and DAS (Distribution Automation System). The IEC 61968 series is intended to facilitate inter-application integration, as opposed to intra-application integration, of the various distributed software application systems supporting the management of utility electrical distribution networks [27]. There are 12 integration modules discussed in IEC 61986, as shown in Fig. 4, and this is in line with the readiness index of vertical-horizontal integration in industry 4.0. The use of common data throughout the value chain is enabled by information systems integrated vertically and horizontally. Information is exchanged continuously between all the IT systems in the value chain. Order information is always linked to the product, work, process instructions, and customer information, and all users access the same data set [8].

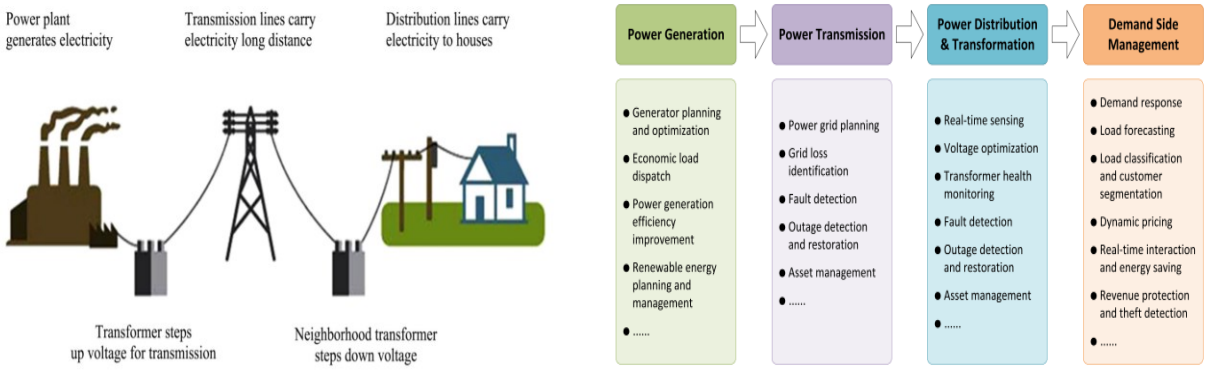
TABLE 3. I4.0 Index in several countries

Model Name	Measurement Context	Content of Pillars	The Intended Use
ACATECH- Industry 4.0 Maturity Index – Germany [8]	-The model measuring maturity, not measuring readiness following the purpose of research. - Can be used as a guide to I4.0	There are four pillars, (1) organisational structure, (2) resources, (3) information system, (4) culture. After the measurement, it is divided into several stages in sequence. Stage one: computerisation, stage two: connectivity, stage three: visibility, stage four: transparency, stage five: predictive capacity, stage six: adaptability	Companies can use this index if they have implemented some or many digital technologies.
PWC- Industry 4.0 Building Digital Enterprise [14]	The model explores the benefits of digitising a company horizontal and vertical value chain, as well as how to build the digital product & service portfolio	There are five pillars (1) *vertical-value chain integration*, (2) *horizontal value-chain integration*, (3) *digital business model,* (4) *product development & engineering,* (5) *customer access, sales channel & marketing*	Companies can use this index if they are currently creating digital portfolios
IMPULS - Industry 4.0 Readiness [15]	The model measure what do business stand and check the readiness for industry 4.0	There are six pillars, (1) strategy and organisation, (2) smart factory, (3) smart operations, (4) smart products, (5) data-driven services. (6) employee. After the measurement, it is divided into several levels in the sequence. Where level one: outsider, level two: beginner, stage three: intermediate, stage four: experienced, stage five: expert, stage six: top performer	Just for companies in the manufacturing sector
SIRI - Smart Industry Readiness Index – Singapore [16]	The index is designed as a comprehensive tool for all companies. Regardless of the size or industry in which they operate.	There are three pillars, (1) process, (2) technology, (3) organisation	Companies can use the Assessment Matrix to evaluate their current digital maturity, benchmark themselves against known scores of other companies and identify potential gaps in their transformation
INDI - Indonesia Industry 4.0 Index [17]	The model measures the readiness of the manufacturing industry to enter the industrial era	There are five pillars, (1) management & organisation, (2) culture & people, (3) product & services, (4) technology, (5) factory operation	Just for companies in the manufacturing sector
A combination of INDI 4.0, Singapore Smart Indexes, Dreamy 4.0, Rami 4.0, Simmi 4.0, TUV [18 ,19 , *20*]	The model measures the readiness of the manufacturing industry to enter the industrial era and is a refinement of INDI 4.0	There are five pillars, (1) data, (2) smart product life cycle, (3) horizontal & vertical integration, (4) design principle of I4.0, (5) I4.0 technology element	Just for companies in the manufacturing sector
Industry 4.0 in the electricity sector [1, 4, 21,22, 23, 24, 25, 26]	There is no specific model that mentions the measurement index, but there are several industries 4.0 keywords in the energy sector	Some literature mentions the technology pillars in the electricity sector, including smart grids, digitalisation, network automation	The ultimate goal of measuring Industry 4.0 readiness in the electricity sector includes: better system operation, reduced costs, increased energy efficiency, reduced greenhouse effect, reduced downtime with, reduced loss/leakage rates, improved energy quality, better management of production and storage systems, intelligent meter reading and load management and real-time supply-demand management, electricity 4.0 (green energy)

TABLE 4. The List of pillars

MODEL NAME	PILLAR	GROUPING
ACATECH	Organisational structure	U
ACATECH	Resources	R
ACATECH	Information System	R
ACATECH	Culture	U
PWC	Vertical value chain integration	R
PWC	Horizontal value chain integration	R
PWC	Digital business model	R
PWC	Product development & engineering	R
PWC	Customer access	R
IMPULS	Strategy and organisation	U
IMPULS	Smart operation	R
IMPULS	Smart product	R
IMPULS	Data driven services	R
IMPULS	Employee	U
IMPULS	Process	R
SIRI	Technology	R
SIRI	Organisation	U
SIRI	Management	U
INDI	Management & Organisation	U
INDI	Culture & People	R
INDI	Product & Services	R
INDI	Technology	R
INDI	Factory Operation	R
ENERGY	Smart Grid	R
ENERGY	Digitalization	R
ENERGY	Automation	R

*U = Unrelated to Technology, R = Related to Technology



(a) (b)

FIGURE 3. (a) Electric power distribution system, (b) Detail activities in power distribution

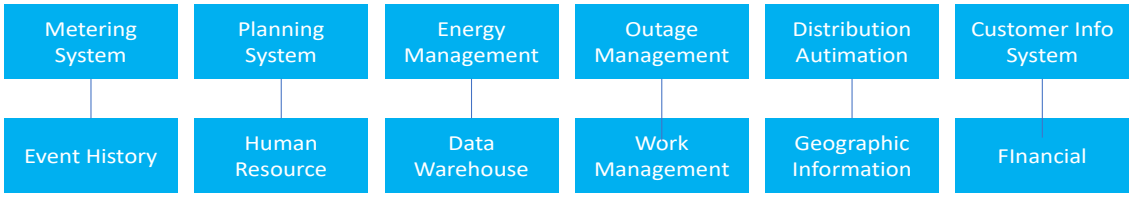


FIGURE 4. Integration module DMS in IEC 61986

RESULT AND DISCUSSION

After doing some literature review, it was found that pillar of INDIST 4.0 for power distribution, as follows:

A. Management & Organisation
   Pillar management & organisation asked how much support from management and organisational form in implementing I4.0. What is the description of the support of management for implementing I4.0 in the distribution division/sub-sector? What is the status of I4.0 strategy implementation in the Company/ Division/Unit? Is there an Investment plan related to I4.0 (Examples of IoT Implementation, Big Data, Robots, Sensors, etc.)? Is there a special department/team in charge of transforming the company (especially distribution) to I4.0? I4.0 implementation requires a proper organisational structure. Organisational structure refers to the company internal organisation. The organisational structure establishes mandatory rules and organises cooperation, both within the company and externally.
B. People & Culture
   People are a very important aspect of the company's transformation process towards Industry 4.0. This includes how the company encourages to development of competence and education in the use of I4.0 technology. In addition, it also measures the culture and works ethic in the company, are you used to changes? Employees who tend to be open to change will be more prepared to transform towards Industry 4.0. On the other hand, employees who are antipathy to change will be much more difficult to implement Industry 4.0
C. Technology
   Technology in Industry 4.0 varies greatly, but if we refer to element technology 4.0 from ACATECH, then real-time capability, Big Data & Analytics, and Decision support systems are the primary keys. In real-time capability, we can provide excellent service and operation to customers. We can know the disturbance that is happening at this time. We can find out the capacity of the transformer in real-time. Meanwhile, Big data & analytics technology supports providing convenience in analysing a problem through the input of some existing data.
D. Digitalisation
   The implementation of digital technology can be carried out in the decision-making process, especially in digitising distribution assets. This pillar aims to determine the digitalization process in power distribution, including digital asset management, IEC module implementation, and mobile & location detection.
E. Connectivity
   Connectivity is required between the engine/sensor and the system in the field. Connectivity can also be found in real-time interconnection with vendors or suppliers partnering with the company. This pillar is used to assess the readiness of the connectivity infrastructure in the enterprise. Matters related to data storage, machine/ system connections, and cybersecurity systems will be analysed.

From the explanation of the five pillars, it can be described in the framework in Fig. 5. We call it INDIST 4.0.

The Readiness index measurement model I4.0 can be helpful for various types and scales of power distribution divisions. This model is not complex and universal to be practical. The I4.0 readiness index measurement model consists of 5 pillars and 15 fields. Each field has 1 and 2 questions, and the total is 20 questions. All question requires an answer on a Likert scale of 0 to 4. At the final stage of the readiness index assessment with a value ranging from 0-5, it is in position 0 for outsider, 1 for beginner, 2 for intermediate, 3 for experienced, and 4 for expert. We can see whether we are currently implementing I4.0 as newcomers, learners or leaders in that position. The sample question is shown in Table 5. The results of measurements show in the spider chart.

TABLE 5. The questionnaire samples

Question	Likert Scale				
	0	1	2	3	4
16. Have all assets, including service personnel, official disturbance cars, and plates/assets been detected geospatially?	Not Yet	Some of the equipment/assets have been recorded geospatially	All equipment/assets have been recorded and some engineering service officers, car service interference geospatial	All Engineering Service Officers, Impaired Service Cars, and equipment/assets have been detected geospatially.	All Engineering Service Officers, Car Service Interference, and equipment/assets have been detected geospatially and in real-time.

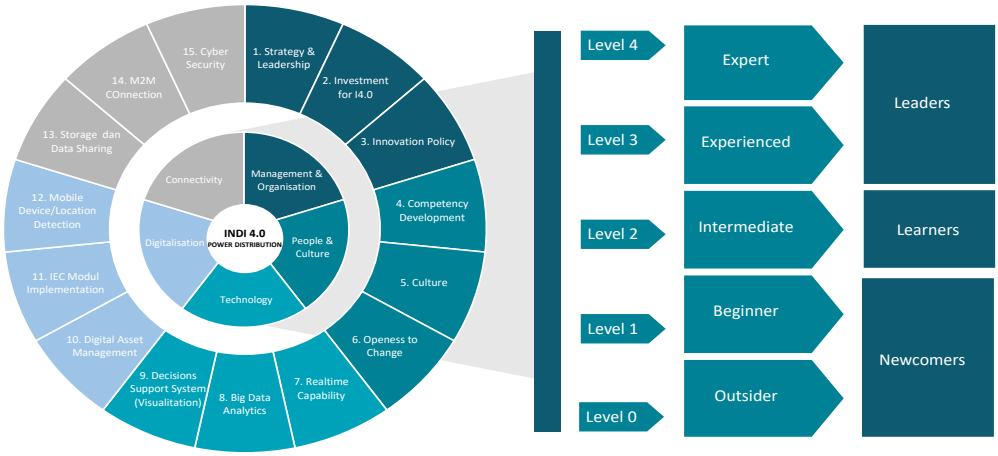


FIGURE 5. Readiness Index 4.0 for power distribution (INDIST 4.0)

Respondents can answer all questions correctly if they have basic knowledge of Industry 4.0 and have a thorough knowledge of the current state of the company's dimensions. Therefore, respondents are at the minimum level of supervisor/manager and can be more than one person according to the dimensions of the company they know. While the measurement method is with the help of an external auditor, in this case, the researcher as an external auditor, respondents can ask questions and discuss if there are statements in the questionnaire that are not or are not understood. To calculate the I4.0 readiness index value can be seen in formulas (i) and (ii)

$$Idx = \frac{\sum_0^4 Fdx}{n} \tag{1}$$

Fdx: The highest number of index values on a scale of 0-4
n: Number of fields on each pillar
idx: Index on each pillar (m = managemen & organisation, p=people & culture, t=technology, d=digitalization, c=connectivity)

$$Index\ 4.0 = \frac{Idm + Idp + Idt + Idd + Idc}{5} \tag{2}$$

The total number of respondents who filled out as many as 71 people with supervisor/manager positions. 71 respondents represented their respective units with a total of 10,010 employees. The distribution of respondents is shown in Fig. 6. After getting answers to 20 questions, it can be seen in Fig. 7. A Spider Chart which shows the I4.0 readiness index for power distribution. The general index value for power distribution in Indonesia is 1.9. The index value of 1.9 is in the beginner position with almost entering the learning level. Over time, the learning process will continue to produce results to realise I4.0 in power distribution.

In Fig. 7, the value of people & culture is the highest value among the other pillars. This indicates that the PLN transformation program is very effective and needs to be continuously improved. PLN conducts a digital transformation program until 2024. Furthermore, the lowest value is on the digitalisation pillar because the digitalisation process is being implemented in stages on Java, Sumatra, and Sulawesi islands. PLN must encourage the acceleration of digitalisation of distribution assets because the assets owned are wide and long. On the other hand, PLN is currently a state-owned company, so there is a possibility of changes in the organisational structure in the next period. The electricity company must have a special division that oversees the I4.0 transformation according to pillar management & organisation.

FIGURE 6. Distribution of respondents throughout Indonesia

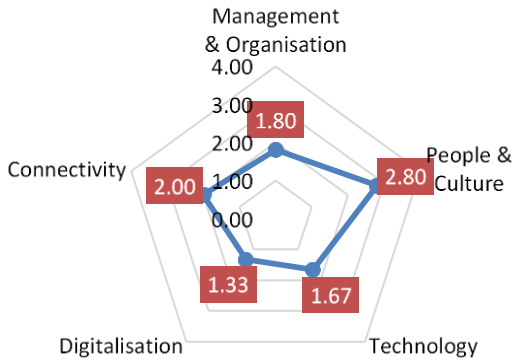


FIGURE 7. Readiness index value in power distribution

CONCLUSION

This research has produced models and instruments for measuring Industry 4.0 readiness, especially in power distribution. There is no specific readiness index model available in the energy sector, especially the downstream electricity distribution sector. This model uses several approaches, including systematic literature studies, conceptual models and qualitative and quantitative methods. The industrial readiness measurement model consists of 2 aspects, namely aspects related to technology and not related to technology. From the results of this readiness measurement, there are three levels of readiness of companies related to Industry 4.0, namely "newcomers", "learners", and "leaders". The target of the Industry 4.0 readiness measurement model is aimed at electric companies in Indonesia who are on the distribution side of electricity. The next research is to identify the weights for each pillar and each variable to get accurate measurement results. As a final note, this Industry 4.0 readiness measurement model does not intend to make the Industry 4.0 transformation process easy and easy automatic. However, this Industry 4.0 readiness measurement model is a tool to assess a company's readiness that reflects the knowledge and abilities possessed related to Industry 4.0 and as a decision-making tool in strategies, work plans and targets in the 4.0 transformation process.

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