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Conventional substation upgrading plans into digital substations in Sulawesi - Indonesia

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Abstract
The focus of Indonesia's G20 Presidency lies on three main pillars, one of them is transition to sustainable energy. The development of these conditions forced State Electricity Company in Indonesia (PLN) to innovate by participating in implementing the latest digitalization technology in distribution electrical energy to customers, one way to do this is by implementing the smart grid concept, which is digital substation technology, is considered capable to response the challenges of digitizing the electricity system in the energy distribution sector. Digital substation technology in Indonesia is still in development stage and there are only six pilot projects in scattered locations, hence in-depth research is needed regarding equipment requirements and the amount of investment needed by PLN to build digital substations, especially the plan for implementing digital substations in Sulawesi. One of methods for developing digital substations in Indonesia is upgrading conventional into digital substation. Research is conducted by studying and observing the existing digital substation in Indonesia. Afterwards in this paper will be explained how to upgrade and what materials, or equipment that must be equipped to upgrading conventional substations. Then, what is the actual value of the investment needed by PLN to build or upgrading into a digital substation in Indonesia, especially in Sulawesi. Furthermore, whether the upgrading plans can be declared financially feasible. The most significant advantages of digital substation compared to conventional substation are reducing the most use of hardwire copper cables for control cables by replacing the use of optical cables. Not only savings in construction costs for the procurement, installation and transportation of cable mate-rials because the amount is much less and is replaced by the use of optical cables, but also construction time savings for laying, wiring and cable termination.

Keywords:
Digital Substation;
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Smart Grid;
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INTRODUCTION

The Indonesian government has signed the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC) on December 21st, 2015, in New York, United States, which is a climate change framework convention organized by the United Nations (UN) [1][2]. Indonesia's commitment through the Nationally Determined Contribution (NDC) document in November 2016 is to set a target for reducing greenhouse gas (GHG) emissions by 29% (own ability) or 41% (with international assistance) by 2030 and renewable energy mix target by 23% in 2025 [3], which is until 2020 the renewable energy mix level has only reached 14.9% (based on IESR 2021). Figure 1 shows the condition.

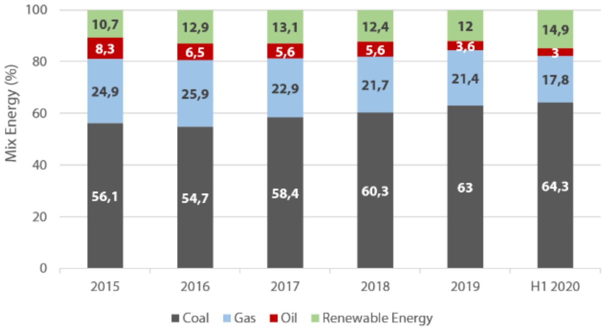

Figure 1. Electricity Generation Mix in Indonesia in 2015 – 2020

The issued to be raised is the plan for converting or upgrading conventional 150 kV substations to digital substations accompanied by financial studies to determine the feasibility level of conversion, upgrading or construction projects for new digital substations. It is currently known that the costs needed to develop smart grids nor digital substations are still quite expensive [4], later with the upgrading plan, several questions arise as follows:

1. How to convert a conventional substation into a digital substation and what materials or equipment must be equipped to convert or upgrade a conventional 150 kV substation into a digital substation?
2. What is the actual cost of investment that PLN need to build a digital substation in Indonesia, especially in Sulawesi?
3. Whether the new digital substation or upgrade plan can be declared financially feasible?

From these questions, will be explained further in this paper.

The fuel mix from January to July 2022 for Northern Sulawesi (Sulutgo) system and Southern Sulawesi (Sulbagsel) systems represented in Figure 2 and Figure 3.

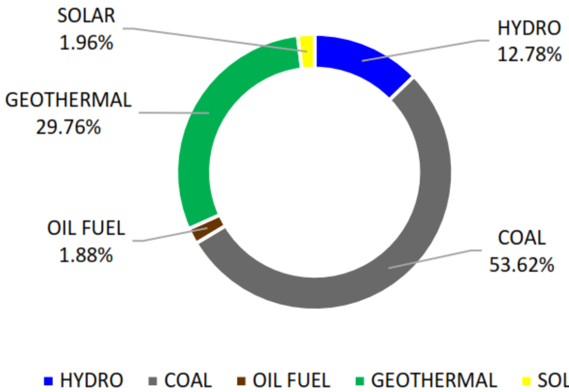

Figure 2. Fuel Mix from January to July 2022 in Northern Sulawesi (SULUTGO) System

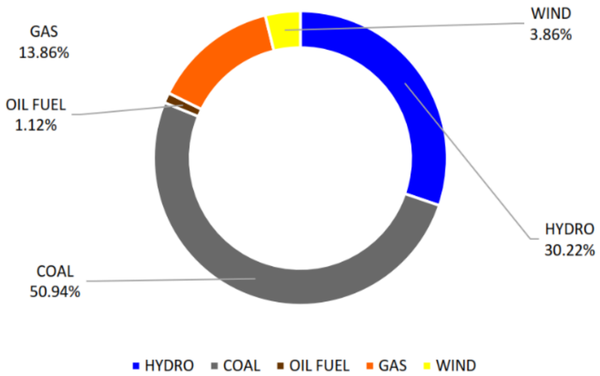

Figure 3. Fuel Mix from January to July 2022 in Southern Sulawesi (SULBAGSEL) System

Based on fuel mix data on Figure 2, we can see that renewable energy fuel mix is approximately on 44.5%, afterwards the discussion will focus by taking samples of conventional 150 kV substations in the existing system of Northern Sulawesi system, due to the suitable or proper in the circumstances of digitalization implementation program in PLN roadmap. Sulawesi has quite unique and challenging electricity conditions, because with limited capacity conditions, it has to face very significant load growth due to the entry of additional demand from high voltage consumers. So that PLN has to force itself to supply and electrify these customers. Therefore, we chose Sulawesi to be our research object.

After that, study will continued with comparing in terms of technology or equipment, as well as in terms of costs or finances, with conventional 150 kV substations that have implemented digital substation technology on Java Island. Then a financial study / analysis is carried out regarding the need for investment costs of the materials or equipment needed at the 150 kV substation so that it can become a digital substation, with reliable controllability and degree of automation, flexible and robust system (including resistance to cyber-attacks [5]).

METHOD

Digital substation technology in Indonesia is still in development stage and there are only six pilot projects in scattered locations, hence in-depth research is needed regarding equipment requirements and the amount of investment needed by PLN to build digital substations, especially the plan for implementing digital substations in Sulawesi. One of methods for developing digital substations in Indonesia is upgrading conventional into digital substation. Research is conducted by studying and observing the existing digital substation in Indonesia.

The mind map of research method started from energy transition, digitalization and operational constraints of conventional substation, as presented in Figure 4. After that proceed with identification of digital substation materials, digital substation development contract value and financial feasibility analysis to convince upgrading conventional substation to digital substation is the best solution.

The results of research data, obtained data related to the implementation of digital substations in Indonesia, those already operating and those still in the construction stage, among others GI 150 kV Jakabaring (South Sumatera), GI 150 kV Sukamerindu (South Sumatera), GI 150 kV Tanjung Api-Api (South Sumatera), GI 150 kV Tanjung Api-Api Extension (South Sumatera), GI 150 kV Teuk Naga II (Banten), GI 150 kV Sepatan II (Banten) dan Upgrading GI 150 kV Bekasi (West Java).

Conventional Substation Surveillance

The current existence of substations technology in Indonesia is generally still conventional because it has not optimized the use of optical cables and still uses hardwired copper as an analog data transaction medium for the control system, but most conventional substations have been prepared to become automatic substations or digital substations that equipped with Intelligent Electronic Devices (IEDs), Substation Automation System (SAS) and ethernet switch.

Physically, a substation consists of two main parts, which is switchyard and control building [6]. The equipment in the switchyard is referred to as HV (high voltage) equipment, including transformer, lightning arrester (LA), capacitive voltage transformer (CVT) and current transformer (CT) as instrument transformer, disconnecting switch (DS), circuit breaker (CB), main busbar and branch busbar, marshalling kiosk (MK), joint box, gantry, and post beam steel structure.

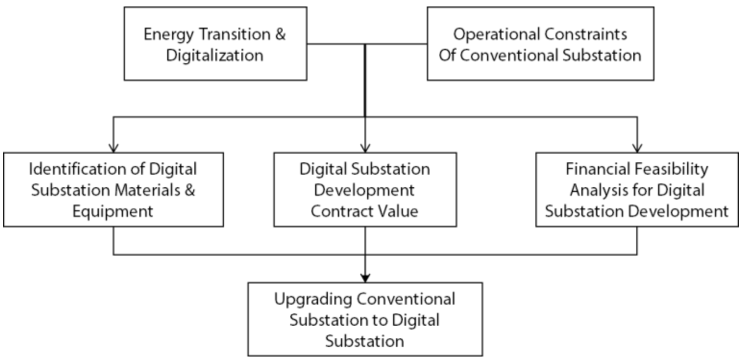

Figure 4. Mind map of research method

The control building in a substation is mostly divided into two sides [7], which are located opposite each other, the first one is the control room side and the second one is 20 kV switchgear side. The equipment in the two rooms is different according to their respective functions. The equipment in the control room, consist of control and protection panel, energy meter panel, telecommunication panel, AC/DC distribution board, battery charger and battery device control panel, and human machine interface as one of the SAS components. Equipment in switchgear room consist of incoming switchgear, outgoing switchgear, bus riser switchgear, busbar voltage transformer switchgear, auxiliary transformer and auxiliary transformer switchgear.

Definition of Smart Grid

Smart grid can be interpreted as an intelligent network that capable to self-healing [8], equipped with dynamic optimization techniques, using real-time measuring equipment to minimize network losses, maintain voltage system and frequency, increase reliability system and optimize assets management [8]. Operational data collected by smart grid and its sub-systems will enable operators' system to quickly identify the best strategy to secure the system against disruptions caused by various possibilities, such as cyber-attacks, system vulnerabilities, intermittency, and so on. Fundamentally, the implementation of the smart grid depends on identifying and measuring the main equipment in the smart grid itself, then proceeding to the design and testing of the main equipment or components of the smart grid, and last but not least, developing competency and skilled human resources for implementation smart grid to this very advanced system [8]. Smart grid technology is widely recognized as being used to improve system stability and reduce power system losses.

Why Implement Smart Grid?

Since 2005, electricity technology, especially smart grid, has begun to develop rapidly. Information and communication technology (ICT) offers an opportunity to modernize the operation of the electricity grid, in line with the concept of decarbonization or net zero emission in the electricity sector which can be significantly reduced if its implementation is executed at a realistic cost if monitored and controlled effectively [9]. This reason became the initial stimulus for interest in implementing smart grids globally.

In addition, there are several basic reasons why many of electricity system company implement smart grids, including, assets are getting older. It is clear, this matter is an absolute reason for rejuvenating existing assets and increasing the capability of the distribution system [10]. Increasing demand and lack of power supply circuit capacity [11]. For example, in RUPTL 2021-2030 it appears that the growth of burden and demand is certain and cannot be postponed nor canceled, in line with economic growth in some region. Therefore, to compensate increasing demand and find solutions to the problem of circuit capacity, it is necessary to add new circuits or upgrading the existing distribution system [12]. Thermal constraints in power delivery. Temperature rise of conductor is directly proportional to the power delivered, so the temperature will be rise until it approaches the maximum capacity of conductor. Similar with the explanation, therefore necessary to add new conductors or upgrading conductors to answer thermal problems in distribution system [12]. Operational constraints with increasingly complexity electricity system. Within increasing demand, the ideas of the concept distributed generation emerged, namely the system operation pattern by connecting the power plant to the distribution medium voltage grid to obtain a robust and reliable electricity system [13]. Security of electricity supply is the main factor considered to serve customers / consumers effectively and efficiently [14]. Modern society requires a more reliable electricity supply, due to higher demand at the connected knot critical points [15]. Conventional way to increase the reliability of the system is to build a new transmission line as an additional redundant circuit, with a large construction cost and environmental impact. Hence the application of smart grid, reliability system can be increased using existing assets by implementing intelligent post-fault reconfiguration so that after a disturbance occurs, the system will be able to record and identify so that disturbances with this pattern can be avoided and mitigated in order that do not reoccur.

Initiatives from developed countries, the governments of these developed countries actively encourage the implementation of smart grids either way to modernize their electric power system infrastructure while integrating renewable energy power plant that is low in carbon emissions at a fairly efficient cost . Smart grid development is seen by many countries around the world as an economic and commercial opportunity to develop new products and services

IEC 61850 Standard Overview

IEC 61850 is an international standard that applies to ethernet-based communications at substations that commonly use SAS devices, these devices are currently widely implemented in existing substations in Indonesia. IEC 61850 provides standard technical definitions, system requirements and function configuration processes of the parameters required for communication between IEDs installed in substation control panels [16] .

IEC 61850 is growing continues to identify every standard requirement by the smart grid equipment manufacturer or developer industry, for example the IEC standard 61850-8-1 and IEC standard 61850-9-2 which are used for the particular construction of digital substations [17].

IEC 61850-8-1 is a relevant standard for bus stations at substations, which facilitates peer-to-peer communication between devices dealing with HMI, the method can be applied by transferring Generic Object – Oriented Substation Event (GOOSE) data between devices on Local Area Network (LAN). Meanwhile, IEC 61850-9-2 is a standard that brings digital instrument transformer (measurement transformer) technology into the power system, breaking through the limitations of conventional CT and VT. This is a breakthrough in the electrical world, playing an important role at the process bus level because it describes the ability to change the value of the measurement sample in the form of an analog signal and then convert it into a digital signal in the non-conventional CT or VT devices .

Digital Substation Understanding

According to V. Kumari and P. Singh explanation in their article entitled "Upgradation of Existing Substation into a Smart Substation" in 2020, basically digital substation is a combination of two elements of technology, specifically telecommunications and electricity [18].

In general, digital substations are substations that optimize the use of fiber optic cables for processing transaction or measurement data (metering) transfer, equipment status data and input/output (I/O status) signals. The data that was originally in the form of analog signal data is converted into digital signal data on the merging unit (MU) device mounted inside the MK at each bay level switchyard. From MU in switchyard, then the data will go to the ethernet switch (ES) for processing and then enter the IED which functions as a protection relay and a bay controller unit (BCU).

Thus, the use of hardwire copper or aluminum or metal alloy materials that were originally used for data transfer with a length that can reach tens of kilometers can be minimized by using optical cables that are much simpler and more compact (with the use of various optical cores), therefore will have an impact on saving cost of building substation itself [19] .

According to IEC 61850, the architecture of the digital substation can be divided into 3 levels, as shown in Figure 5, namely station level, bay level and process level [20], with the following explanation, Station Control Area or commonly called station level, integrated through a Wide Area Network (WAN) as a communication medium between the master station (dispatcher room) and HMI equipment at substations located in the electricity system or sub-system [15][20]. Protection and control level or commonly called bay level, includes control and protection equipment for each bay (line bay, transformer bay or coupler bay) at the substation that is integrated with the IED and connected by ethernet switch which as the estuary of FO cables connected to MU from MK in the switchyard [21]. Process level is the foremost level in acquiring data, signals and measurement results from the main transmission equipment both conventional and non-conventional equipment with fiber optic (FO) cables intermediary media at the switchyard. FO cables acts as a substitute for hardwire, which of course requires additional equipment commonly called MU to convert analog data into digital data, so that the signal / data can be sent via the FO cable to the IED at bay level [7][22].

Network Redundancy on Digital Substation

With implementation of the redundancy protocol will allow the emergence of alternative paths for sending data from source to destination. There are two types of redundancy protocol, which are active redundancy and passive redundancy. The active redundancy type is a redundancy protocol that has two active links at the same time.

While the passive redundancy type only has one active link, and one other link is in standby mode. The redundancy protocols commonly used are Rapid Spanning Tree Protocol (RSTP), High Seamless Redundancy (HSR) and Parallel Redundancy Protocol (PRP) [3], as presented in Figure 6.

HSR is specified regulated in clause 5 of the IEC standard 62439-3:2016 and provides zero-delay failover in case of failure and is compatible for both protection systems and SAS. The HSR redundancy topology is similar to RSTP, the difference is that two-way data transmission is configured simultaneously with a looping scheme [3].

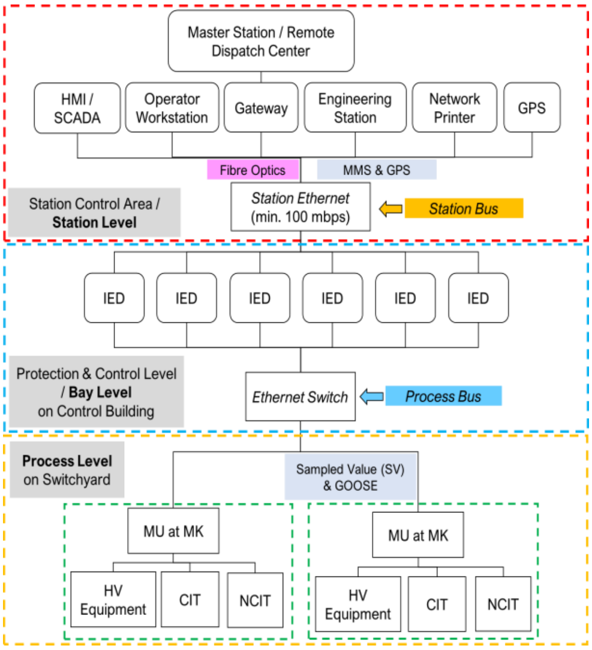

Figure 5. General Digital Substation Architecture

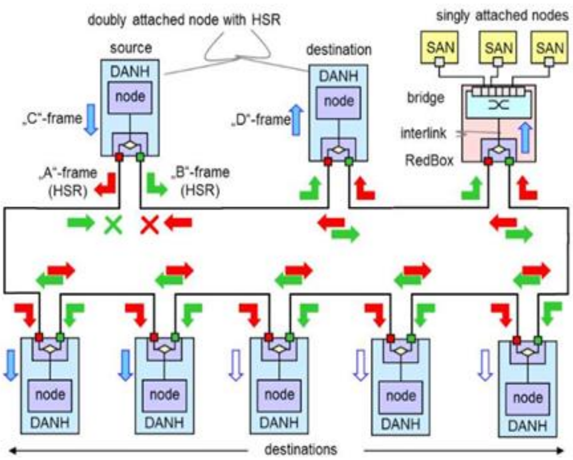

Figure 6. HSR Protocol According to IEC 62439-3

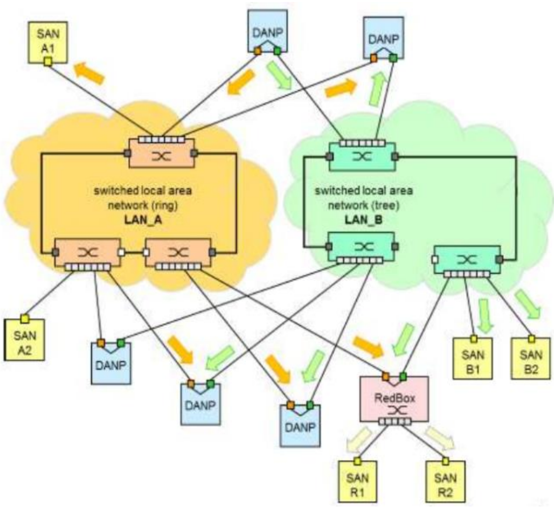

Figure 7. PRP Configuration According to IEC 62439-3

PRP is a redundancy protocol with 2 layers that facilitates zero disruption or seamless failover in the event of a connection interruption or drop link connection. PRP is specifically regulated in clause 4 of IEC 62439-3:2016, as shown in Figure 7.

Project Feasibility Affecting Factors

PLN as government representative, prioritizes the economic aspect, because the electricity that is distributed will be very beneficial for the surrounding people, although financially it has a less positive impact on the company [25].

However, it is necessary to calculate financial feasibility of development of electricity infrastructure, especially digital substations as a consideration of government policies in developing new and renewable energy potential.

Factors and parameters that influence the feasibility (financial assessment), are as follows:

1. Discount rate is one of the economic parameters that states the rate of return and the interest rate experienced due to capital loans invested by investors or creditors [23].
2. Weighted average cost of capital (WACC) is the average rate of return (which is calculated by weighting) that must be provided by the company as a project manager to investors or creditors with the intention of increasing interest to investing. The capital consists of 2 components, namely the value of equity and the value of debt, each has cost and must be weighted based on the level of contribution to the company's capital structure. For investors, the WACC value is the return-on-investment (ROI) value; while for companies, WACC is an expense.
3. Net present value (NPV); is the current value of money by comparing the estimated value of money in the past or the future using the discount rate factor, or it can be interpreted that the NPV is obtained from the result of the reduction/difference from the cash flow that produce against the investment value (initial capital) issued.

$$NPV = \sum_{t=0}^{n} \frac{Ct}{(1+i)^t} - I \quad (1)$$

NPV = Net Present Value
Ct = Cash flows value that occur at the end of t - year
n = Number of project's lifetime estimation
t = 0, 1, 2, . . . n
(i) =Cost of capital for project implementation
I = Initial investment value

4. Future Value is an estimation calculation related to the current value of money for the future by being influenced by interest rates or inflation rates or certain growth rates [24].

$$FV = PV(1+r)^n \quad (2)$$

FV = Future Value
PV = Present Value
r = interest rate or inflation rate
n = n – year

5. Internal rate of return (IRR); is a general project feasibility assessment to determine the rate of return on investment. If IRR value is less than discount rate, then the investment is declared not feasible for execution, otherwise, the investment can be declared eligible for execution [26].

$$IRR = I' + \frac{NPV'}{NPV' - NPV"}(I' - I") \quad (3)$$

I' = interest rate that gives positive NPV value
I" = interest rate that gives negative NPV value
NPV' = positive NPV
NPV" = negative NPV

6. Benefit Cost Ratio (B/C); is a comparison ratio between the total value of present cash flows (during the economic life) and the value of the initial expenditure of the project (capital investment). If the B/C value > 1 then the project can be declared feasible, but if the B/C value < 1 then the project is declared not feasible.

$$Conventional\ B/C = \frac{B}{C} \quad (4)$$

$$Modificated\ B/C = \frac{B-(O+M)}{CR} \quad (5)$$

B = annual worth benefit
C = annual worth cost
CR = capital cost recovery
O+M= annual operation and maintenance costs

7. Payback Period (PBP); is the required period or time to return the capital investment which is calculated from the net cash flow with period per year.

$$Payback\ Period = \frac{a-b}{b-c} x\ 1year \quad (6)$$

a = initial investment value
b = cash flow cumulative amount in n - year
c = cash flow cumulative amount in n+1 year

To assess feasibility of a project, according to criteria as shown on Table 1.

RESULTS AND DISCUSSION

From research and field observations, the following results were obtained as shown on Table 2. In order to upgrading a conventional substation into a digital substation, the following steps are required, as follows in order to upgrade conventional substation into a digital substation requires an assessment of the equipment condition, the operation and maintenance scheme, whether the existing substation is feasible or not for upgrading. The assessor team appointed by the owner (in this case is PLN) to conduct the assessment, of course, they must have good experience and competence, to obtain quality recommendations and proposals in assessing and considering whether go or not go to execute the upgrading conventional substation into a digital substation. Based on the observations and research that has been done, it is known that several equipment and items needed to support a digital substation, among others, as listed in Table 3.

Table 1. Financial Feasibility Parameters

Parameter	Feasible	Not Feasible
Payback Period (PBP)	PBP < Target Periode	PBP > Target Periode
Net Present Value (NPV)	NPV > 0	NPV < 0
Internal Rate of Return (IRR)	IRR > cost of capital	IRR < cost of capital
Benefit Cost Ratio (B/C)	B/C > 1	B/C < 1

Table 2. Digital Substation Development Status in Indonesia (August 2021)

Substation	Specification	Status
GI 150 kV Jakabaring (South Sumatera);	3 transformers bays, & 2 line bays;	New construction & already in operation (2013);
GI 150 kV Sukamerindu (South Sumatera);	3 transformers bays, & 2 line bays;	New construction & already in operation (2013);
GI 150 kV Tanjung Api-Api (South Sumatera);	2 transformers bays, 2 line bays, & 1 bus coupler bay	New construction & already in operation (2013);
GI 150 kV Tanjung Api-Api *Extension* (South Sumatera);	2 line bays;	New construction & already in operation (2017);
GI 150 kV Teluk Naga II (Banten);	2 transformer bays, 4 line bays, & 1 bus coupler bay;	New construction (2017) & construction completion stage;
GI 150 kV Sepatan II (Banten);	2 transformer bays, 2 line bays, & 1 bus coupler bay;	New construction (2017) & already in operation (Agustus 2022);
Upgrading GI 150 kV Bekasi (West Java).	5 transformer bays, 4 IBT bays, 2 capacitor bays, 12 line bays, 2 bus coupler bays, & 2 bus tie bays.	Upgrading (December 2021) & construction completion stage.

Table 3. Main Supporting Equipment of Digital Substation

Required Works / Equipment	Placement	Note
SAS Hardware and Software Devices	Operator control room;	If conventional substation has not implemented SAS;
Fiber optic (FO) cables	Up to all bays in substation and along the trans-mission line;	In the form of ADSS or OPGW;
HMI	Operator control room;	Parts of SAS hardware and software devices;
Ethernet Switch, Server, and Gateway	Mounted on each control protect-ion panels in substation control building;	Redundancy protocol-based architecture, compliant with IEC 61850 standards;
MU	Every each MKs in switchyard;	The main device to converting analog signals into digital signals;
GPS	Mounted on communication panel in control building;	Installed together in communication panel;
IED (BCU / SCU and MPU / BPU)	Mounted on each control protection panel;	Use of IEDs varies depending on the manufacturer;
NCIT	Every bay in switchyard;	Its utilization is still optional, according to requirement of the user in electricity system;
Configurator and testing tools	Types of service work and provision test equipment;	It is mandatory because it's related to engineering works, commissioning and troubleshooting processes in operation and maintenance activities;
Civil works	Switchyard, control building and/or switchgear building.	As the main supporting works in construction of control building and digital substation switchyard.

Table 4. Value Comparison of New Digital Substation Construction and Upgrading Conventional Substation to Digital Substation

Description	New Construction (Million Rp)		Upgrading (Million Rp)
	Teluk Naga	Sepatan	Bekasi
Total Value Before Tax (PPN)	132,120. -	105,182. -	39,997. -
PPN 11%	14,533. -	11,570. -	4,399. -
Total Value After Tax (PPN)	146,653. -	116,752. -	44,396. -
Future Value	164,609. -	131,047. -	44,396. -
Average Value Each Bay	23,515. -	26,209. -	1,644. -

Determination of Investment Value

From the Table 4, the new construction of digital substation based on the construction value / price reference in November 2017. The upgrading construction conventional substation to digital substations based on the construction value / price reference in December 2021. So that these references is still be able to be considered relevant for financial analysis.

Thus, the average value per bay = Rp 24,862,528,626.- or rounded up to Rp 24.8 billion / bay for the construction of a new digital substation. Meanwhile, the average value of upgrading conventional substation to digital substation is Rp 1,644,315,068.- / bay or rounded up to Rp 1.6 billion / bay. Those values are excluding the cost of land acquisition and the cost of the permit process related to construction development.

Digital Substation Implementation Plan in Sulawesi

Consideration and background of the plan for implementing digital substations in Sulawesi, are as follows, implementation of new digital technology (digitalization) in the energy distribution sector. Increasing electricity system demand. Reducing the number of operators or outsourcing manpower for new assets, forcing PLN to innovate in the operation and maintenance of energy distribution grid. Budget availability for PLN to invest in new technology implementation.

Afterwards, information was obtained that the plan for implementing digital substation technology in Sulawesi is to upgrade the existing conventional 150 kV substation to digital substation. The substation that has the potential for upgrading are GI 150 kV Tanjung Merah in North Sulawesi Province, GI 150/70 kV Puuwatu in Southeast Sulawesi Province and GI 150 kV Bantaeng in South Sulawesi Province.

Reasons in the selection process for substations to be upgraded regarding several parameters, including the substation load level is quite low in electricity system, making it easier to turn off the system during the construction process. The substation location is quite close to the master station, so that the operation of the intended substation is controlled periodically and can be monitored remotely. Take precedence substations that already have SAS and HMI, as well as the number of bays in the substation.

Digital Substation Construction Development Financial Feasibility Study

The calculation of financial feasibility study is carried out using the investment value for upgrading conventional substation that adjusted for the number of existing substation bays, selected location for simulations were carried out on GI 150 kV Tanjung Merah (North Sulawesi). The initial data shown on Table 5. From the assumptions mentioned, financial feasibility is then calculated to obtain the PBP, NPV, IRR and Benefit Cost Ratio values, with the following results, as listed in Table 6.

Based on the research results, the advantages and disadvantages of implementing a digital substation are explained compared to conventional substations in Indonesia.

Table 5. Initial Data of GI 150 kV Tanjung Merah

Description	Value
Initial asset value (August 2022)	Rp 101,606,774,087.- (7 bays)
Conventional substation upgrade value	Rp 1,644,315,068.- / bay
New digital substation value	Rp 24,862,528,626.- /bay
Production cost of Northern Sulawesi system	Rp 1,724.- / kWh (August 2022)
Discount rate	9,1%
Economic age	20 years
Operation and maintenance	2%
Tariff rate	Rp 1,433.- / kWh
Dispatching capacity	90 MVA

Table 6. Financial Feasibility Study Resume Calculation for Upgrading GI 150 kV Tanjung Merah

Items	Value
PBP	17 Years
NPV	Rp 202,045,347,563.-
IRR	12.64
B/C	2.78
Final Result	**Feasible**

Table 7. Comparison of Digital Substation and Conventional Substation

Items	Digital Substation	Conventional Substation
Data Transactions Between Equipment	Reducing the use of hardwire copper cables for control cables by replacing the use of optical cables (fiber optic cables).	Using copper wires for data transactions (control and metering functions), using analog data.
Safety Factor	It is considered safer for humans during maintenance process, because there is no electricity in the installed optical cable.	The electricity is still stream in control cable during maintenance, so standard operation procedure for the implementation of maintenance is needed according to the working permit and safety regulations.
Investment Value	Savings in construction costs for the procurement, installation and transportation of cable mate-rials because the amount is much less and is replaced by the use of optical cables. As well as cost savings (procurement, installation and transportation), due to the use of NCIT type CMO (combined measurement optical) unit.	The required investment value is still in accordance with the current market price. The price difference is generally influenced by the location, manufacturer, and distribution capacity of the substation.
Cons-truction Duration	Construction time savings for laying, wiring and cable termination. For the optical cable pull for the control function, there is only one optical cable pull per bay (1 cable pull = 24 cores) compared to the control cable pull which is quite a lot in conventional substation.	Requires point-to-point control cable pulling, so it requires a long construction time compared to digital substations.
Space Requirement	The size of the protection control panel is smaller (60cm x 60cm), so the space required for panel placement is smaller. The use of NCIT type CMO can save space in the switchyard, because it combines two equipment functions in one HV equipment.	The size of the control and protection panels in conventional substation is 80cm x 80cm (wider than digital substation panels). In switchyard still uses conventional CT and conventional PT or CVT.
Measurement Instrument	The use of NCIT type CMO can save space in the switchyard, because it combines two equipment functions in one HV equipment	In switchyard still uses conventional CT and conventional PT or CVT.
Recovery from Disturbance	In the event of a system disturbance, it facilitates the identification and trouble-shooting process due to all information and data is already available on HMI, so that the recovery process can be handled in a shorter time.	The recovery process is still quite time consuming, because there is still minimal digitization in identifying disturbances.
SCADA Implementation	Optimizing the SCADA function, because it is able to facilitate the operation process in the process of controlling, monitoring and accessing data (with low time delay) on all installed equipment by reason of everything is connected by optical cable.	Not all conventional substations have implemented SCADA (especially in Indonesia).
Maturity Technology	Digital substation technology is generally still in the development and pilot project stage.	The technology is already mature.
Interoperability	is still constrained with interoperability matters when implementing digital substations with different manufacturers.	There are no interoperability constraints.
Network Configuration	The configuration process is quite complicated and take time. Manpower issue, due to the network and equipment configuration process is a vital problem and the ability / skill of the engineer to configure each equipment according to needs. Competent and experienced engineers are currently few in number and need knowledge sharing from the expert team for the engineer regeneration process.	Minimal configuration process and the existing manpower is quite experienced.
Cyber Security	Cyber security issues arose in several locations, due to weakness level of security for the operation of digital substations that were integrated into systems using ethernet switches.	The operating system is still manual and local operation (with the operator on standby in front of the panel).
Standards and Regulations	There are not any standards (SNI and/or SPLN) yet that regulate the implementation (construction, operation, maintenance, and testing of equipment).	Standards are clearly regulated in SNI and/or SPLN.

CONCLUSION

Upgrading conventional substation to digital substations is only 6,61% compared to the value of new digital substations. It appears that all aspects have met the requirements of the project's financial feasibility, so it is feasible to execution.

The results of observations and research on digital substation projects in Indonesia, concluded the most significant advantages of digital substation compared to conventional substation are reducing the most use of hardwire copper cables for control cables by replacing the use of optical cables (fiber optic cables). Not only savings in construction costs for the procurement, installation and transportation of cable mate-rials because the amount is much less and is replaced by the use of optical cables, but also Construction time savings for laying, wiring and cable termination, as presented in Table 7.

The most disadvantages of digital substation is still constrained with interoperability matters when implementing digital substations with different manufacturers and there are not any standards (SNI and/or SPLN) yet that regulate the implementation (construction, operation, maintenance, and testing of equipment).

Field observation methods, case studies in Indonesia and financial studies were carried out to determine the level of project feasibility . For further research can be developed related to testing and operating digital substations in Indonesia

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