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500-kV XLPE Underground Cable Line Construction for Sustainainability Electric Power Transmission in City Centers

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Abstract. 500-kV Underground Cable transmission line design is a type of design that has never been applied in transmission line construction in Indonesia. Even around the world, 500 kV Underground Cable designs are still limited scale. Actually, electric power transmission line grid systems in Indonesia with a voltage rating 500 kV has been applied, but only in Java island with Overhead Line transmission line model, and it's a backbone of the Java-Bali power grid system. Currently, PLN have a Jakarta Looping transmission system project 500 kV Extra High Voltage. This project has a potential delays due to land problems and social constraints along the route. Given that Jakarta is a capital city with a very high population, the construction of a tower transmission line will be a special challenge to complete the transmission project, where the process of land acquisition and compensation costs under along the route (ROW) will also be a special thing. In this research, we will try to estimate the construction cost for the 500 kV Underground Cable as an alternative to the project for other types of aerial cables. The route length will be adjusted into 4 categories of the overhead line route 1)a half of the overhead line route, 2)same with the overhead line, 3) 1.5 times of overhead line, and last 4) 2 times of overhead line. From the estimated calculations with these 4 categories, it is obtained the ratio of construction costs with underground cable designs to the overhead line design is smaller than cost of ratio for the same project design in Europe and/or America. It's feasible to execute in urban area like Jakarta, Surabaya and Bandung, but not feasible for outside urban area.

Keywords*:* Overhead line, Underground cable, Cable, 500 kV, Transmission, Investment cost, Construction Cost, Ratio.

Abbreviations: OHL (Overhead Line), HDD (Horizontal Directional Drilling), EMF (Electromagnetic field).

Running title: Sustainainability Electric Power Transmission.

INTRODUCTION

The development of electricity infrastructure and a high level of electrification is expected to be a driver of national economic growth where in the last 10 years an average of 1 kWh of electricity consumption in Indonesia has contributed $ 3.9 to GDP (Source: BPPT). PLN is carrying out some efficiencies to reduce BPP costs so that electricity rates to the community can be kept low, one of which is by optimizing the operation of coal /steam power plants, accelerating the completion of the PLTU project and related transmissions for the evacuation of power from outside Jakarta to the area as load center in Jakarta because steam power plants (PLTU) provide greater efficiency in electricity production so that it will have an impact on suppressing the electricity BPP (Djoko R. Abumanan, PLT President Director of PLN, 2019). In 2020, the PLN seeks to complete the construction of a strategic and prestigious project, namely the construction of the 500 kV Extra High Voltage transmission to be able as flow and increase the supply of electrical energy in the surrounding Jakarta load center areas (Ratnasari Sjamsudin, 2019), so that it can reduce basic costs electricity supply (BPP) and maintain the sustainability of the electricity supply to the community.

PLN has a project, that is 500-kV Jakarta Looping Trasnmission, that are SUTET Duri Kosambi-Muara Karang section, SUTET Muara Karang-Priok, SUTET Priok - Muara Tawar and SUTET Muara Tawar-Bekasi. All transmission segments above are planned to be implemented with the construction of the OHL (Overhead Line) tower transmission design.

The main obstacle in the construction of this overhead line transmission network is the issue of land acquisition for the tower site, social problems along the transmission line and the limitation of vacant land that can be used by PLN for the construction of the transmission.

Beside it, constraints to the construction of SUTET transmission towers have long been a national issue in our country, because it is suspected have a negative impact for human health. The rejection of the construction of the SUTET has even occurred since 1991 when PLN for the first time built a 500 kV transmission on the Java Island (Lolita Adhyana, KILAT, April 2020). All these problems ultimately increase the high investment costs that must be incurred by PLN. In addition to construction costs in the physical construction contract, PLN should also pay compensation value for residents who own the land, plants, house/building along the transmission line as regulated by PERMEN ESMD No. 27/2018 concerning Compensation for land, buildings and / or plants that are under the free space of the transmission network electrical power.

Another problem faced with this OHL design is the pressure and demand from the provincial government of DKI Jakarta, that the SUTT / SUTET transmission line currently in Jakarta has been instructed to immediately be lowered into a ground cable, it will maintain the beauty / aesthetics of the airspace of Jakarta. This is an obstacle to build a new transmission line. Given that the city of Jakarta is the center of economic growth with the potential for growth in electrical energy that is quite large, the constraints in the construction of this type of over head line transmission can pose a threat to the fulfillment of demand and reliability of electricity supply.

To overcome licensing problems, land acquisition for tower treads, as well as social impacts along the transmission line plan, the author tries to study the construction of this extra high voltage overhead transmission line (SUTET) with the design of an underground cable or also known as 500 kV XLPE Underground Cable to be able to applied instead of OHL design. The study was carried out in terms of construction design, construction costs, investment costs, permits, implementation time duration, material fabrication, expert, environmental beauty and maintenance operation processes.

From the research of the 500 kV AC underground transmission in UK by AESO, said that *installation estimated for 500 kV underground cable transmission system are 7 to 10 times higher than 500 kV by overhead lines* (Fred Ritter, P.Eng).

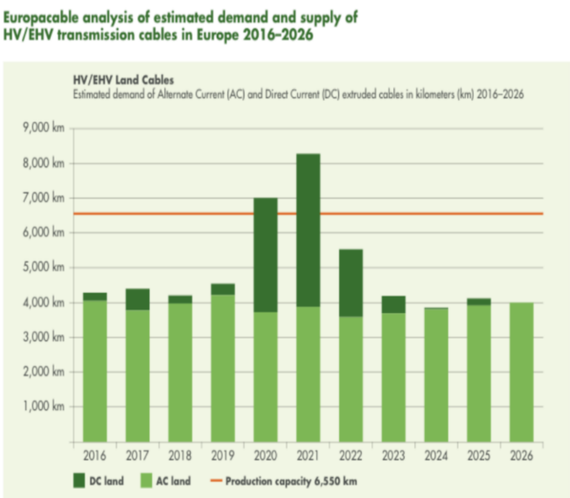
From table-1 below, in European countries, the use of the overhead line type transmission is still very dominant, reaching 52% of the total length of the existing transmission, while the processing for the underground cable type is still very small, namely 4% from the total cable length.

Table 1. Transmission line in Europe in 2016.

2016 TYNDP	Km	% km	Projects	% projects
Overhead Line	21,230	52	199	68
Subsea Cabling (incl. some land parts)	18,075	44	54 subsea 14 mix subsea&land cable	24
Land Cabling	1,511	4	11 land; 14 PUGC	8
Total	40,816	100	292	100

Source. : Europa Cable.

However, based on analysis data from Europa Cable, it is estimated that there will be a demand for the use of land and submarine cables reaching 90,000 km, both for the Hight Voltage and Extra Hight Voltage ratings in 2016-2026 (Source : Europa Cable).



Negara	Underground Cable (kmr)		Perubahan (%)
	1996	2006	
Autralia	42	73	74%
Autria	48	59	23%
Kanada	250	151,5	-39%
Denmark	31	52	68%
Perancis	600	914	52%
Jerman	99	110	11%
Irlandia	64	106	66%
Italia	130	231	78%
Jepang	873	1563	79%
Belanda	6	12,5	108%
Spanyol	31	558	1700%
Swedia	11	35	218%
Swiss	25	13	-48%
Inggris	553	662	20%
USA	6	1198,2	19870%

Figure 1. European Cable Analysis of estimated demand of HV/EHV on 2016-2026 (Source : EuropaCable) and Comparation of 1996 and 2006 data lengths (km) of Underground Cable in the range 220 kV to 500 kV (Source : CIGRE, 2007).

In 2006, CIGRE conducted a survey to measure the development of underground cable transmission use in many countries in the world, with rated voltage 110-219 kV, 220-362 kV, 363-500 kV. The results of the 2006 survey are compared with the results of the same survey method that was conducted in 1996 ago. In Figure 1 above, a comparison of the use of underground cable transmission in many countries in the world that uses a voltage rating of 220 kV to 500 kV is shown. *It can be seen that most countries have reported an increase in the amount of underground cable since 1996*, but some of the changes (for example the decreases in Canada and Switzerland and then *almost 20000% increase in cable in the USA* reflect changes in the efficiency of data capture rather than changes in the amount of cable installed).

Failure rate for XLPE cables in the 220 kV – 500 kV range of 0.133 failures / year-100 kms (Source : CIGRE Technical 379). Based on the statistical information from CIGRE, for one circuit with a length of 170 km it is estimated that 9 or 10 faultswould occur over the period of 40 years.

This paper aims to see how using of underground cable designs with aerial cable designs can be compared, in terms of construction costs, investment costs, ease of physical construction, and the relationship with the operation maintenance.

MATERIALS AND METHODS

For the study in this paper, the use of the 500 kV extra high voltage ground cable used refers to the design and implementation of the 500 kV XLPE underground cable that has been carried out in several countries such as Japan, China and America, while the size and configuration of the cable is adjusted to the ampacity requirements in PLN project. OHL design with the ampacity of transmission line max is 3300 A/circuit which is planned according to the system requirements that will be used on the transmission line Duri Kosambi - Muara Karang, Priok – Muara Tawar and Muara Tawar – Bekasi. The cable route plan will be made based on the survey results taking into account the shortest distance, access factor and the presence of existing utilities such as water pipes, gas pipes, telephone lines, and rivers as well as ground contour conditions. For cable length requirements, the route length will be adjusted to the 4 (four) length categories of the overhead line route, that is *1)a half of the OHL length route, 2)same with the OHL length route, 3) 1.5 times the length of the OHL route, and last 4) 2 times the length of the OHL route*. This length adjustment is necessary because the length of the underground cable route is not necessarily equal to the length of the OHL route. Other designs will be adapted to the design and standards that apply to 500 kV cables. Other indicator data will be taken from ground cable projects with a lower voltage rating, namely 150 kV which has been widely implemented in Jakarta, but will be adjusted to the need for an extra high voltage rating of 500 kV. Meanwhile, data related to OHL design will be obtained from previous projects as well as data on going project.

RESULT AND DISCUSSIONS

Construction

The difference in the design of the OHL and UGC transmission is that the UGC construction is a cable that is laid underground. For the depth of the cable minimum is 3 meter under the top ground level (according to the regulations of the DKI Jakarta provincial government) where at a certain distance there is a Joint Pit construction or also called a Joint Box. The primary function of the Joint Box is for splicing/joint the cables during construction and for permanent access, maintenance, and repair of the cables. The number of joint box required for an underground transmission line is dictated by the maximum length of cable that can be transported on a reel, the cable's allowable pulling tension, elevation changes along the route, and the sidewall pressure as the cable goes around bends. Joint box can be either prefabricated and transported to the site in two pieces or constructed onsite. Excavations in the area of the joint box will be deeper and wider. Higher voltage construction may require two joint box constructed adjacent to each other to handle the redundant set of cables. As for the cable laying construction method, there are several methods that are often used, such as manual boring method, open cut or direct buried method, Horizontal Directional Drilling (HDD), cable ducting method, or cable laying in the tunnel. Among the cable laying methods, the method with the lowest cost is the direct buried method. Another methode that can be used is cable laying on air or in the open air with a cable rack/stell support.

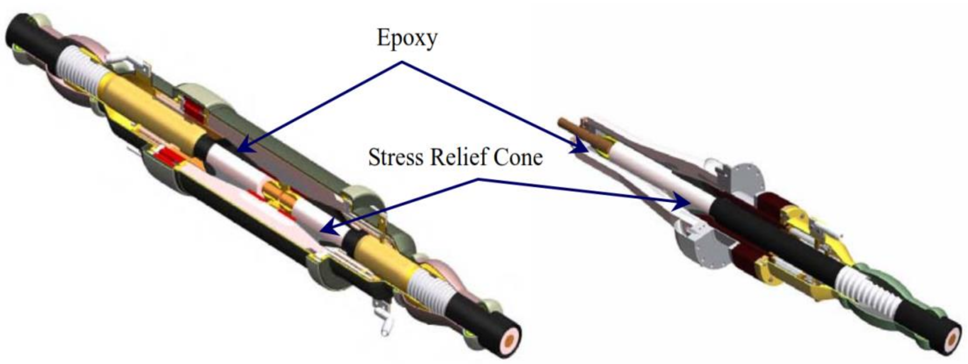


Figure 2. 500-kV Cable Joints and GIS Termination Model.
Source : Statistic of UGC in Power Network, CIGRE 2017.

Many people ask if transmission lines can be placed underground rather than overhead. While many lower voltage, local electric distribution lines are placed underground, particularly in newer neighborhoods, almost all high-voltage electric transmission lines are overhead for four general reasons: environmental impact, cost considerations, construction measures and operational issues. Because of these issues, underground transmission lines typically are justified only where there is no space for overhead corridor, such as in densely populated urban areas or around the airports area. For underground infrastructure, XLPE cable is nonobtrusive; immune to weather; highly reliable with high energy efficiency and high emergency rating; and has low electromagnetic field (EMF).

Right of Way Construction Zone

Similar to overhead transmission construction, underground construction begins by staking the ROW boundaries and marking sensitive resources. Existing underground utilities are identified and marked prior to the start of construction. If the transmission line is constructed within roadways, lane closures will be required and traffic control signal installed. Construction activities and equipment will disrupt traffic flow. When materials and equipment are delivered, traffic may be closed. Another alternatif could be taken, by doing delivered equipment or material in the mid night when the lowest condition of the traffic. Construction areas need to be wide and level enough to support the movement of equipment and other necessary activity.

Transporting Cable Drum

Given the size of the cable drum / haspel which is quite large and heavy, transportation to the project site needs to be done with special mobilization with heavy equipment, such as using low belt trucks and forklits or cranes to transport cable drum. The weight of the XLPE cable material is about 51.3 kg / meter of cable (Source : TAIHAN Cable 500 kV), so for 1 cable drum with a length of 500 meters cable, the total weight of the cable drum can reach more than 25 tons. Specifically for the conditions of transport this cable drum material in Jakarta, the dimensions of the height of the toll gate must

be considered during the material transportation process, considering that the exit road access from Tanjung Priok Port must go through by toll road access which has limited height and width of the toll gate. Meanwhile, the transportation of cable drums from the cable origin manufacturer to Indonesia is carried out by sea transportation. For information, XLPE cable manufacturers in Indonesia have not been able to produce XLPE cables with a voltage rating of 500 kV, so all the cable materials and related accessories for the construction of 500 kV underground cables are imported materials.

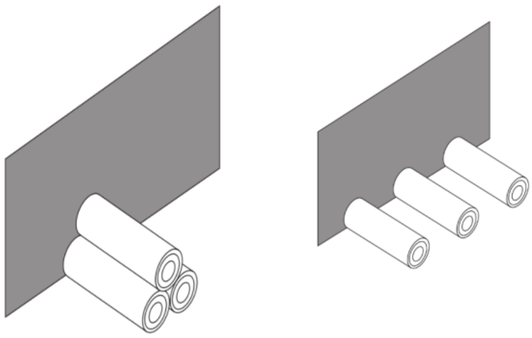
Cable Laying or Cable Installation

The method of cables laying can be done in several ways, such as dirrect buried, manual boring, or the Horizontal Directional Drilling (HDD) boring method. It is also can be placed in a tunnel, in ducting or on the ground with a cable rack (stell support). Given the size and tonnage of these cables which are quite large and heavy, the pulling of the cables is carried out with the machines, winches or hauling machines and cable roll.

Figure 3. Ducting Cable
(Source : Western Transition Station T&D World).

Cable Formation

There are 2 types of cable formation after laying them down, namely: the first Trefoil formation and the second is the Flat formation. In Figure 4 below, you can see a cross-sectional image of the cables that have been laid, flat and trefoil formation with 1 core per phase 1 circuit. If needed, it can also be made with 2 cores per phase 2 circuits, also with flat and trefoil formations.



a) trefoil formation
b) flat formatioan
Figure 4. Underground Cable Formation
Source : www.nexans.com

Site Recovery

Site recovery for underground construction is similar to overhead transmission line construction restoration. When construction is completed, roadways, landscaped areas, and undeveloped areas are restored to their original condition and topography. Highway lands and shoulders are re-constructed so as to support road traffic. Roadside areas and landscaped private properties are restored with top soils that was previously stripped and stockpiled during construction or with new topsoil. Any infrastructure impacted by the construction project such as driveways, curbs, and private utilities are restored to their previous function, and yards and pastures are vegetated as specified in landowner.

Hight Volt Cable Testing

One scope of work that is different from the OHL is the work of testing the high voltage on the cable from end to end (end to end testing) after all cable joint is complete and terminations at both side ends are also finished, be it indoor type or outdoor type. This test requires a special test equipment tool. Based on IEC standards, the high voltage test on the cable is carried out for 1 hour (60 minutes) for each the R-S-T phase. If all three phases have passed the test, the underground cable transmission is ready to operate. However, if there is a failure in one of the cable phases, the cable test failure point must be repair first before re-testing and ensuring the cable is ready for operation.

Construction Cost and Investment

The price of underground cable is strongly influenced by fluctuations in the commodity price of raw materials such as copper. It is also expensive to manufacture and store large stocks of cable, particularly for the very high voltages. In consequence the price of underground cable is very sensitive to the balance between demand and manufacturing capacity.

The security and reliability of underground infrastructure, along with regulatory issues and public demand, are factors. Cost ultimately may be the deciding factor, it is important to note that the gap between underground cable and over head line construction costs has narrowed. The common rule of thumb once was that underground was 20 times more expensive than over head line. *Today, the gap generally used is that underground costs 10 times more* (Source : Brian Dorwart, P.E, Undergorund Electric Transmission Installation Gaining Traction, June 2010).

Factors influencing the cost include, but are not limited to, the following:

- **Routing**–RoW, easement and permitting costs and whether the line will be placed in the road right-of-way
- **Terrain and obstacles**–Other underground utilities, streams and railroad crossings, embankments, bridges, major roads, traffic and soil conditions
- **Permitting**–Traffic and lane restrictions, noise, time of day and other construction restrictions
- **Design**–Mitigating soil thermal characteristics

Underground construction could be a reasonable alternative to overhead in urban areas where an overhead line cannot be installed with appropriate clearance, at any cost. In suburban areas, aesthetic issues, weather-related outages, some environmental concerns, and the high cost of some ROWs could make an underground option more attractive.

Put the cables underground is a significant part of the cost of a project. The cost varies widely depending on the ease of access along the route and the amount of power to be transmitted. In urban areas, the costs of cable installation would be significantly higher than in the countryside. In the city, there are likely to be a large number of crossing with another services, for example gas, water, telecommunications or maybe another power cable system that have been lay before. The trench walls usually have to be supported in order to work safely. Additional costs arise from the need to manage the traffic flow and from the restrictions often paced on the hours of working in order to reduce inconvenience to local residents. In rural or open areas, the costs of cable installation are likely to be reduced. A mechanical excavator can often be used to dig the trench and there may be sufficient space and suitable soil conditions to dig a trench with unsupported sloping walls.

The cost of installation can also be reduced by the use of mechanised laying techniques. The cable trench can be excavated, the cable laid and the trench backfilled in a single pass. For larger cables mechanised laying techniques can be used to bury plastic ducts. The cables can subsequently be pulled into the ducts. Under the certain conditions in which a cable has to be connected to an overhead line whose rating is far greater than the present day need. It may be economic to install a cable that meets the present day requirements and then install a second cable per phase once the load has grown sufficiently. For a ducted cable system it may be more economic to install spare ducts during civil work for the initial installation

In Table-2 below, it can be seen that the construction costs are carried out with XLPE Underground Cable construction, section of the 500 kV Underground Cable Duri - Kosambi Muara Karang transmission project with a transmission length of approximately 12 kilometers route, with the required length of 2 x CU XLPE cable that needs to be supplied is 148,32 km of cable.

Tabel 2. Estimating Cost for 500 kV XLPE Underground Cable Section Duri Kosambi - Muara Karang.

No	Description	Qty	Sat	Price
1	*Cost relating works carried out by local authorities*	*1*	*Lot*	*USD 68.027,21*
2	*Procurement for XLPE Single Core Cable size 2000 sqmm*	*148320*	*M*	*USD 74.664.489,80*
3	*Straight joint box cable*	*276*	*Pcs*	*USD 5.632.653,06*
4	*Erection for straight joint box*	*276*	*Pcs*	*USD 3.755.102,04*
5	*GIS Sealing End for 1 x CU 2000 sqmm*	*24*	*Pcs*	*USD 489.795,92*
6	*Erection for GIS Sealing End Indoor Type size 2000 sqmm*	*24*	*Pcs*	*USD 326.530,61*
7	*Joint Pit Construcion*	*46*	*Pcs*	*USD 782.312,93*
8	*Horizontal Directional Drilling (HDD) Boring*	*24000*	*M*	*USD 40.816.326,53*
9	*Laying Cable by direct buried metohe*	*24000*	*M*	*-*
10	*Test Commisioning*	*1*	*lot*	*USD 68.027,21*
			Total	**USD 126.603.265,31**

Whereas in Table-3 below, it can be seen that the project cost for 3 sections of Jakarta Looping if all of it design and construction using 500-kV XLPE Underground Cable construction.

Tabel 3. Estimating Project Cost for 500-kV XLPE Undergound Cable.

No	Project	Length (kmr)	Cable Configuration	Project Cost
1	*UGC Duri Kosambi - Muara Karang*	*12,0*	*2 CU x 2000 sqmm ; 2 cct*	*USD 126.603.265,31*
2	*UGC Priok – Muara Tawar*	*18,3*	*2 CU x 2000 sqmm ; 2 cct*	*USD 192.833.645,71*
3	*UGC Muara Tawar – Bekasi*	*18,4*	*2 CU x 2000 sqmm ; 2 cct*	*USD 193.852.897,96*

The construction cost value for the 500 kV Underground Cable Duri Kosambi-Muara Karang in 2 circuit CU 2x2000 sqmm is estimated more than USD 126 million. This value is 6 times greater when compared to the value of construction with overhead line designs, which are currently contracted for USD 21,465,238. In terms of construction costs, it is clear that there are striking differences between these two types of design, the construction cost of the underground cable is greater than the cost of the OHL design.

However, for consideration of costs investment by PLN, the over head line design must also take into value of the cost of land acquisition for the tower site, ROW compensation costs along under the line and the potential delay in construction completion due to the incomplete land acquisition and ROW compensation, considering that the line route of the over head line plan path crosses densely populated urban areas and settlements with high land values.

The width of the ROW span is 14 meters to the left and 14 meters to the right of the axis tower according to the internal provisions of PLN, that is SPLN No. T5.006 -2019 concerning "*Ruang Bebas dan Jarak Bebas Minimum pada Saluran Udara Tegangan Tinggi (SUTT), Saluran Udara Tegangan Ekstra Tinggi (SUTET) dan Saluran Udara Tegangan Tinggi Arus Searah (SUTTAS)*".

Table 4. Minimum horizontal clearance from the vertical tower axis.
Source : SPLN 2019.

No	Saluran Udara	Jarak dari Sumbu Vertikal Tower/Tiang ke Konduktor L* (meter)	Jarak Horizontal Akibat Ayunan Konduktor H (meter)	Jarak Bebas Impuls Petir atau Impuls Switsing I (meter)	Total L+H+I (meter)	Pembulatan (meter)
1	SUTT 66 kV Tiang Baja	1,80	1,37	0,63	3,80	4,00
2	SUTT 66 kV Tiang Beton	1,80	0,68	0,63	3,11	4,00
3	SUTT 66 kV Tower Rangka Baja	3,00	2,74	0,63	6,37	7,00
4	SUTT 150 kV Tiang Baja	2,25	2,05	1,50	5,80	6,00
5	SUTT 150 kV Tiang Beton	2,25	0,86	1,50	4,61	5,00
6	SUTT 150 kV Tower Rangka Baja Dua Sirkit	3,85	3,76	1,50	9,11	10,00
7	SUTT 150 kV Tower Rangka Baja Empat Sirkit Vertikal	3,85	3,76	1,50	9,11	10,00
8	SUTET 275 kV Tower Rangka Baja Dua Sirkit	5,80	5,13	1,80	12,73	13,00
9	SUTET 500 kV Tower Rangka Baja Sirkit Tunggal	12,00	6,16	3,10	21,26	22,00
10	SUTET 500 kV Tower Rangka Baja Dua Sirkit	6,85	6,16	3,10	16,11	17,00
11	SUTET 500 kV Tower Rangka Baja Empat Sirkit Vertikal	7,30	6,16	3,10	16,56	17,00
12	SUTET 500 kV Tower Rangka Baja Empat Sirkit Horizontal	20,35	6,16	3,10	29,61	30,00
13	SUTET 500 kV Compact Tower Rangka Baja Dua Sirkit	5,37	5,06	3,10	13,53	14,00
14	SUTET 500 kV Compact Tower Rangka Baja Empat Sirkit Vertikal	5,37	5,06	3,10	13,53	14,00
15	SUTET 500 kV Tiang Baja Dua Sirkit	4,98	5,06	3,10	13,14	14,00
16	SUTET 500 kV Tiang Baja Empat Sirkit Vertikal	4,98	5,06	3,10	13,14	14,00
17	SUTTAS 250 kV	7,40	4,30	1,70	13,40	14,00
18	SUTTAS 500 kV	9,00	5,30	3,30	17,60	18,00

Meanwhile, the estimated compensation value for land under the ROW line refers to ESDM Ministerial regulation No. 27/2018 concerning "*Kompensasi atas tanah, bangunan dan atau tanaman yang berada di bawah ruang bebas jaringan transmisi tenaga listrik*", calculated based on the formula of the amount of compensation value = 15% x Lt x NP (market value of land prices). After calculation, the estimated total value of land compensation for 12 kmr of this transmission line is USD 23,857.143, -. We can see that estimating cost value for compensation under the ROW line is more higher than project cost construction.

Thus, the estimated investment cost value in the construction of this transmission with the design overhead line is USD 21,465,238.0 for construction and USD 23,857,143.0 for compensation for the land under free space, with a total value of USD 44,322,381, - . Then, we can compared to the underground cable design as calculated above, the construction with an underground cable design is still more expensive, which is **approximately 3 times** than the overhead line design.

The only reliable method of comparing overhead and underground costs is on a case by case basis. Generic values of cost ratio are of very limited use and should be avoided. Estimates for the costs of underground and overhead options for a specific project must be calculated and then weighed against the advantages and disadvantages of each option.

Table 5. Estimating Cost Ratio-Underground Cable to Over Head Line.

Project Title	Project Cost Construction		Construction Cost Ratio (UGC to OHL)	Invesment Ratio		Invesment Cost Ratio (UGC to OHL)
	OHL	UGC		OHL	UGC	
Duri Kosambi-Muara Karang	USD 21.463.238	USD 126.603.265	5,90	USD 44.322.381	USD 126.603.265	2,86
Priok-Muara Tawar	USD 39.799.721	USD 192.833.646	4,85	USD 74.664.579	USD 192.833.646	2,58
Muara Tawar-Bekasi	USD 38.768.200	USD 193.852.898	5,00	USD 56.292.010	USD 193.852.898	3,44

The cost ratio in Table-5 above, is for the same length of the underground cable transmission route as the length of the over head line route. With the scheme of underground cable route lengths is 0.5, 1.5 and 2 times from the length of the over head line route, the cost ratio can be shown in the Table-6 below :

Table 6. Estimating Cost Ratio-Underground Cable to Over Head Line in different scheme.

PROJECT	UGC Route 0.5 x OHL Route		UGC Route 1 x OHL Route		UGC Route 1.5 x OHL Route		UGC Route 2 x OHL Route	
	Construction Cost Ratio (UGC to OHL)	Investment Cost Ratio (UGC to OHL)	Construction Cost Ratio (UGC to OHL)	Investment Cost Ratio (UGC to OHL)	Construction Cost Ratio (UGC to OHL)	Investment Cost Ratio (UGC to OHL)	Construction Cost Ratio (UGC to OHL)	Investment Cost Ratio (UGC to OHL)
Duri Kosambi - Muara Karang	2,96	1,43	5,90	2,86	8,84	8,84	11,77	5,70
Priok – Muara Tawar	2,43	1,29	4,85	2,58	7,26	7,26	9,68	5,16
Muara Tawar – Bekasi	2,51	1,73	5,00	3,44	2,49	7,49	9,99	6,88
Average	2,63	1,49	5,25	2,96	7,86	4,44	10,48	5,91

Major Material

One of the most significant differences in these two types of designs is regarding the supply of the main material in the construction. In construction with overhead line, basically all the main materials can be produced in the local factory Indonesia. Starting from lattice tower design, raw material and fabrication lattice tower, string set insulators and conductors, all the material are available in local manufacture. But, for the 500 kV XLPE Underground Cable, all the main major materials including the enginnering still have to be imported from foreign manufacturers because the cable material, cable straight joint and sealing end indoor/outdoor types, Indonesian's manufacture have not been able to produce XLPE 500 kV cable size 2000 sqmm. This is also one of the reasons that causes the construction price of 500 kV underground cable to be very expensive.

Beside the cable, there is also a straight joint material, the specialized expertise needed to make the joint cable and could be acquired and scheduled for the initial installation, however this expertise is limited base on current market demands. Additionally, acquiring that same expertise on short notice as would be required for repair of a failed single segment could be very difficult and could substantially lengthen the time required for return to service. In summary, qualified personil to make joint cable for 500 Kv are small world wide community (Feaseability Study for 500 kV Everglades National Park).

Environment Impact

The construction impacts of underground lines are temporary and for the most part, it can recovery. It is include dirt, dust, noise, and traffic disruption. Increased particles in the air can cause health problems for people who live or work nearby. If the right-of-way is in a residential area, construction hours and the amount of equipment operating simultaneously may need to be limited to reduce noise levels. In commercial or industrial areas, special measures may be needed to keep access to businesses open or to control traffic during rush hours. Most underground transmission is constructed in urban areas. In non-urban areas, soil compaction, erosion, and mixing are serious problems, in addition to dust and noise. After cable construction, trees and large shrubs would not be allowed within the right-of-way due to potential problems with roots for the cable. Some herbaceous vegetation and agricultural crops may be allowed to return to the right-of-way. Another issue after the cable construction such as aesthetics, electric and magnetic fields, and property values are usually less of an issue for underground lines. Underground lines are not visible after construction and have less impact on property values and aesthetics.

Safety

Overhead lines are highly visible structures and are rarely damaged unintentionally by third parties. However, if people get too close to high voltage overhead conductors fatalities can occur. Falling conductors and masts also are a danger in extreme conditions. As underground cables are not readily visible, it is not uncommon for these to be damaged by excavators, drilling operations and suchlike. This can cause major damage and injury, but the incidence of such events is rather low, as cable protection systems operate extremely quickly, and the underground locations tend to limit the spread of fire and hazardous materials. In most countries, contractors are encouraged to contact the relevant utilities before commencement of excavations; this is mandatory in certain countries. It is generally accepted that underground cable is more secure than overhead cable. Cause acts of nature can cause outages, and these days, there's the possibility ... a terrorist strike can cause grid failure. Aerial lines are exposed to hurricanes, ice and snow, wind and other natural disasters and overhead cables can be easily accessed for sabotage. Underground infrastructure is far less vulnerable to such risks and, thus, may be considered more reliable.

Operation and Maintanance

All electric lines produce heat and therefore have a limit on the amount of power that they can carry. Underground lines cannot dissipate heat as well as overhead lines. Factors such as electrical insulation, the type of surrounding soil, adjacent underground utilities and the depth of installation all affect the wire's ability to dissipate heat. New underground lines can have higher thermal ratings than outdated overhead lines they are replacing; however, there is far less flexibility to make improvements as needed on underground lines. When lines are above ground, replacing wires or making other improvements can often be done without significant disruption.

In temperate countries, an overhead line can provide a more secure electricity supply than an underground cable, as an overhead line is not subject to damage from digging activities by third parties, which may be considerable (often due to the non observance of the permits and laws). However, in extreme weather conditions, this is not necessarily the case. Wind, snow and storms can cause extensive damage to overhead systems, while underground systems are immune from them. Damage from falling trees can also be a problem for overhead lines, particularly for lower voltages lines. This is less of a problem for very high voltage lines with their taller towers.

Where overhead lines cross areas of poor soil stability, the foundations of towers must be strengthened accordingly. Similar approaches can be used with underground cable, for example installing the cable in piled troughs or reinforced concrete duct banks. The cost is correspondingly higher because the strengthening is required along the entire route rather than being restricted to the tower positions.

Beside it, there are continued maintenance and safety issues associated with the right-of-way. The right-of-way must be kept safe from accidental contact by subsequent construction activities in the future. To protect against accidental future dig-ins, a concrete duct bank, a concrete slab, or blocks are installed above the line, along with a warning signs (WARNING : High-Voltage Cable Line).

In the case of an overhead line, a fault can be quickly found by visual means using either a manual line patrol or in urgent cases, by helicopter patrol. Repair the overhead lines is relatively simple in most cases and the line can usually be put back into service within a few days. However, major catastrophic failures do occur involving multiple circuits and can take many months to repair. In some cases the use of temporary support structures allows rapid restoration of the overhead circuit. Underground cable failures tend to affect only a single circuit. An underground cable fault can be difficult to locate by electrical means, if obvious excavation damage is not present, and typically takes one to several weeks to repair (Xcel Energy, Colorado) with the condition material spare is available to use.

Table 6. Indicators

No	Indicators	Remark
1	*Construction*	*Planned the underground cable line on the public or commercial acces area, not private area.*
2	*Construction Cost and Investmen*	*Maintain the depth of the embedded cable above the ground level according to the design for optimal current capacity of the cable.*
3	*Major Material*	*Find the shortest route distance for line route.*
4	*Environment Impact*	*Maximize the length of the cable from the manufacturer that can be accommodated on the project site in 1 pull to reduce the number of cable joints and the number of joint box construction.*
5	*Safety*	*Using the XLPE Cable material from the manufacturer with competitive price.*
6	*Operations and Maintanance*	*Dirrect burried or manual boring method for cable laying is the lowest price and will reduce installation cost.* *Use the XLPE Cable with have Type Test Certificated that has been proven* *Underground lines are not visible after construction and have less impact on property values and aesthetics.* *Ensure the accuracy of the as-built drawing regarding the position and depth of the cable, if other utilities will utilize the same area, they know the position of the cable accurately* *Considering that all 500 kv underground cable materials are imported and also the 500 kv transmission line as the backbone of the grid system, it is advisable to prepare a spare of straigh joint material as mitigation if the cable is damaged during operation by third parties due to drilling or excavation as long as local product cannot used.*

CONCLUSIONS

In general, underground cable lines project are significantly more expensive than overhead lines. In this case, cost ratio for the 500-kV Underground Cable line in average is almost **3 times** more expensive from the overhead line for the same length route, when the overhead line have consider all cost due to ROW along the route. In addition, if the route length of UGC is just a half of the OHL route, then the average cost ratio is **1.5 times** more expensive than the OHL design. However, if the length of the underground cable route reaches 2 times than the length of the OHL route, the average cost ratio will be increase up to **6 times** greater than the OHL design.

Seeing the above, to plan the underground cable line, the length of cable route must be determined by the shortest route and planned under the public or commercial acces area, not in to private area to reduce the cost for landowner and cost of project construction. This is similar with the data shown in Table-2 that for underground cable construction, the major cost is for the procurement of cable material up to 58% of the project cost construction. The value of this cost of ratio is smaller than the same case in Europa and America that have the cost of ratio is around 10-20 times more expensive.

Furthermore, it is necessary to develop further and in-depth studies for other aspects of the 500 kV Underground Cable when the cable line must be positioned under the river in a depth of 12-15 meters down, current carring capacity of the cable and the impact for the cable length needed or changing the size of the XLPE cable, finally will be impacted for the overall cost of underground cable design.

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