Borneo Journal of Sciences & Technology, Volume (3), Issue (1), Pages: 15-20
DOI: http://doi.org/10.3570/bjost.2021.3.1-03
e-ISSN: 2672-7439

Submitted: 02nd Jun 2020 Accepted: 05th September 2020 Published: 31st January 2021

HV Power Transmission between Sarawak and Peninsular Malaysia by Suspending Wires within Oil and Gas Pipes

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Abstract: Power transmission across the globe is vital for economic growth. Secure and reliable electricity infrastructure is important for good integration process. The South East Asian countries are forecasted for continuous growth for next few decades. In line with that power demand is also expected to increase from 789 TWh in 2013 to about 2200 TWh in 2040. The South East Asian region is made up of many islands but there is no electric grid connected to share power supply. This region is also rich in renewable energy such as hydropower, solar and wind. A smart integration will definitely promote regional growth. Therefore, this research focusses on enabling electric power transmission across South China Sea. In 2011, Bakun Dam in Sarawak, Malaysia with 2,400 MW installed power production capacity was commissioned. There were studies made by electric industry to utilize expensive XLPE based submarine cable for power transmission across 630km between Sarawak and Johor, Malaysia. Unfortunately, the overall conclusion was the losses will be too high to be practical. But we do have successful transmission of long-distance overhead transmission lines across many parts of the world. Therefore, this research attempts to create overhead lines conditions under the sea by suspending bare transmission cables at the center of oil and gas pipes which is an established technology.

Keywords: Power sector, renewable energy, submarine cable, cross-linked polyethylene (XLPE), electric transmission within pipes

INTRODUCTION

South East Asia (SEA) has a high potential of becoming a renewable energy hub within Asia. The Philippines is the largest wind power generator in SEA with a target of 593 MW by 2030. Indonesia has embarked her exploration on geothermal power. It is believed that almost 28,000 MW of potential geothermal energy is available within Indonesia due to its volcanic geology. Malaysia is becoming a solar hub for many solar manufacturers. With the potential supply of solar panels at a cheaper rate and plenty of sunlight throughout the year, Malaysia can generate substantial amount of power through sunlight. On top of that, Sarawak being the biggest state of Malaysia has a high potential of generating power through many hydro dams. At present 2.4 GW Bakun, 944 MW Murum and 108 MW Batang AI dams are operational and there are plans to build many hydro dams within Sarawak as shown in figure 1.

This clearly shows that there is a huge potential of energy generation through renewable source. So, it is pivotal to establish a good electric connectivity in order to fully tap into potential renewable energy. At this point of time there is no proper energy integration from one country to another especially grid connectivity from one island to another.

Figure 1: Sarawak's Power Generation and Network

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The main objective of this research is to establish a method to transmit hydro power generated in Sarawak to Peninsular Malaysia. A smart grid connectivity is important in enabling the utilization of renewal energy. This was also determined by electrical experts in Europe and in the USA. In Europe the Synchronous Grid of Continental Europe (SGCE) connects the grids of 24 countries [1]. In the USA the Tres Amigas SuperStation designed to interconnect three major grids of USA. This project will provide solar, wind and other renewable developers with the transmission infrastructure needed to transport clean electricity.

The Malaysian government through The Energy, Science, Technology, Environment and Climate Change Ministry (MESTECC) has set a target of 20% of the country's electricity to be generated from renewable sources by 2030. Our current composition shows that we are only producing at about 2% rate from renewable energy source. This initiative was aimed at increasing the renewable energy mix in electricity supply and reduce consumption of coal and fossil fuels. This initiative will indirectly help to reduce the greenhouse gas emissions too.

For more than 10 years, the member states of ASEAN have been working towards closer integration, with one of the milestones – the single-market ASEAN Economic Community (AEC). In addition to seamless movement of goods, services and people across ASEAN, there is also an initiative to link the electricity supply, transmission and distribution networks of member states into a single ASEAN Power Grid (APG).

Every region has their most potential energy source. Hydropower is identified as most viable energy source for Sarawak, Malaysia. The two factors that affect the ability to produce hydroelectricity, namely, the head (height) and the flow (or quantity) of water. This makes hydroelectricity optimal. The advantages of hydroelectric are not only that it is free energy but is a magnet for industrialist who can easily get loans from the world's largest banks which tend to more easily approve loans to build factories when the source of energy is clean [1].

Indonesia on the other hand can optimally develop geothermal energy because its position on the Ring of Fire. Therefore, drilling short holes will be enough to obtain the geothermal energy [2].

There is not much technology in place now to connect the ASEAN grid. This is mainly because ASEAN countries comprises of many islands such as The Philippines, Borneo and Sumatra. A submarine XLPE based cable was proposed during the construction of the Bakun dam. The total estimated initial cost to build the dam was at RM6.5 billion. This budgeted amount was almost the same to establish XLPE cable between Sarawak and Peninsular Malaysia. [1] So, this clearly shows that submarine cables are not cost viable.

The longest submarine XLPE HVDC power cable in the world so far is between Netherlands and Norway. The cable distance is 580 km and capable to transmit 700 MW [1]. The longest bare O/H transmission lines is 3,284 km long carrying HVAC 12 GW between Changji and Guquan in China. Therefore, as can be seen the O/H transmission lines can carry 17 times more AC power over 5 times the distance of submarine cables.

MATERIALS

The proposed cross section view of the cable in pipe as shown in Figure 2. Cable is suspended in the middle and supported by ceramic insulators.

This design proposes nitrogen (N_2) to be the main source of gas to prevent any corrosion along the 630km long pipe. Apart from preventing corrosion, nitrogen will also act as an insulator between the cable and carbon steel pipe.

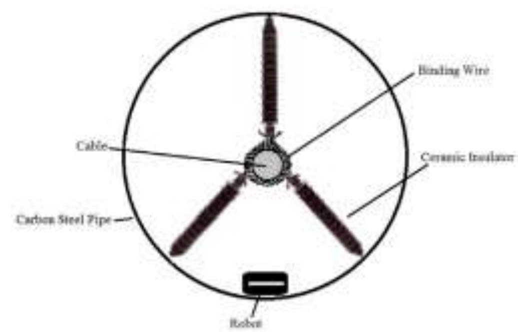

Figure 2: Cross sectional view of the structure of the pipe

The only foreseen issue of placing a HV cable within a pipe is the build-up of heat. Anyway, the estimated temperature on the South China Sea is about 22ºC compare to 27ºC normal temperature of O/H HV lines in Sarawak. Apart from that, flow of N_2 within the system will help to dissipate the overall heat. Additional factor about this platform is one of the shallowest seas in the world. This will definitely help to ease the laying of the pipes. This region is called the Sunda-Self with estimated depth range of 20-50m [3].

There is multiple size of pipe used in the Oil and Gas industry. The pipe size ranges from 4" upto 72". In this research an estimated 8" pipe should be sufficient to carry the electric cable from Sarawak and another 4" diameter pipe can bring back the N2 from Johor. A pump to be placed at Johor to increase the pressure to enable it to go back to Kuching via a 4" Ø pipe seamlessly.

It should be noted that a lot of the expenditure of the pipe is to dig the sand up to 5m deep and laying weights to prevent buoyancy, therefore laying these two pipes at the same time is not going to increase cost too much.

The only literature on such a system is the GIL (Gas Insulated Line) [4]. GIL system was invented by engineers at Massachusetts Institute of Technology in 1965. The basic structure of the GIL consists of N2 and SF6 gases inside the enclosure encircling an aluminum conductor. GIL design with all the components are as shown below (Figure 3).

Figure 2 shows the cross-sectional view of the pipe design. The conductor wire is supported by three ceramic insulators. Ceramic material is stable and lasting but the any stress during the installation process can cause damage and defeat the purpose of being a supporting agent [5]. An option to use FRP (fibre-reinforced plastic) insulators should also be studied. Meantime, cleaning robot to maintain the whole system is an option.

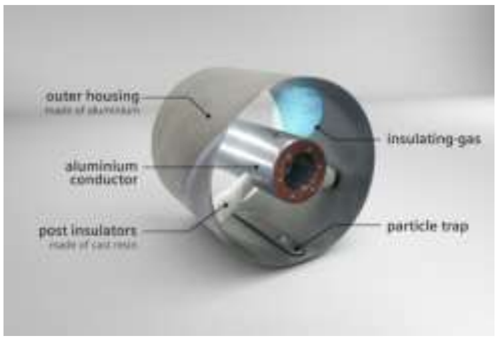

Figure 3: A cross section view of a modern GIL showing its various components (Source: Siemens website)

The voltage can be specified to be 1000kV and the 500mm^2 cable can handle 546A. This will enable a power transfer of 546MW.

The proposed implementation method as described below. At the factory, a set of three ceramic/FRP insulators will be installed. Each insulator will be spaced 120 degree within the pipe. Oil and gas industry pipe is measured at 11.3m in length. Barges are used to place the pipes and cables are pulled from the drum and inserted from one end to another. Before submerging the pipes into the sea, cable must be supported by the three insulators. Next another pipe is joined to the first one and clamped by circumferential heater. This is how two pipes are joined together. After the joint work, pipes are kept for a while for cooling purpose and the similar work is continued for the subsequent pipe.

A communication fibre optic line will also be bound to the top of the star shaped insulators. The latest development in fibre optic sensors enables measurement of most physical parameters and its multitasking ability will enable it to operate infrared cameras, moisture sensors to detect leak and heat sensors.

METHODOLOGY

The focus of this research was to measure the losses in this system assuming the standard O&G steel pipes were to be used. The overall design of this system is with an AC conductor in the middle will generate eddy current within the carbon steel pipes.

There are altogether 8 carbon steel pipes were purchased as shown in Figure 4. Copper wire was used for this experiment as we know this type of material is a good conductor. The cross section area of the copper wire is 2.5mm2. Each 2.5mm2 copper wire can handle current up to 21A. So, for this experiment we use 4 copper wires which can handle up to 84A. To simulate the actual transmission, four length of 3m wire was stripped off its PVC (polyvinyl chloride) insulator. One end was tied to the frame and the other end connected to MCCB/Isolator.

Figure 4: The carbon steel pipes.

The incoming power supply setup as shown in figure 5. Fuji MCCB placed at the incoming point and 30ft electrical cable run through the lab to supply the required current.

Figure 5: Electrical wiring to enable experimental work

The experimental setup is shown in Figure 6. A simple but reliable structure was setup in order to collect all relevant experimental data.

The load for this experiment comes from 132 incandescent bulbs of 100W each. These bulbs are connected in parallel with 12 bulbs in each row. So, in total 11 parallel circuits are established through this setup. Each row of bulbs is connected with a switch. During the experiment individual row of bulbs are switched on one by one to achieve the varying current. Through the varying current we are able to determine eddy current (potential energy loss through joule heating).

The same measurement was taken for 8 different diameters of pipes. The diameter of the pipes is shown in Table 1. AC in the pipe will have eddy current generated provided spacing between the conductor and the pipe surrounding is not sufficient. So, through this experiment the intention is to extrapolate data obtained to determine diameter of the pipe which the eddy current loss is negligible. Target current is at the range of 1000A.

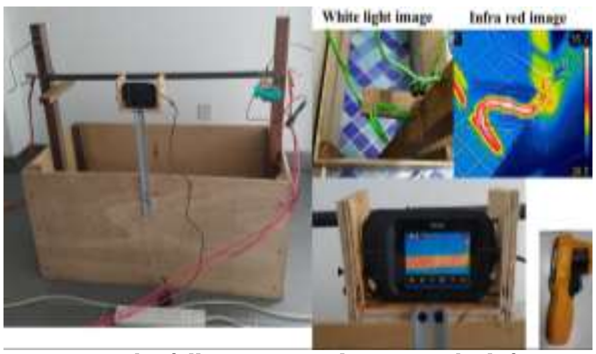

Figure 6: The full experimental setup on the left. Top right is FLIR C2's two images: white light and infrared. The right bottom is the FLIR C2 camera used and to its right is the Fluke model 62 MAX used to confirm measurement.

Initially all 132 bulbs will be lit and after half hour, the heat measurement is taken. Next another circuit of 12 bulbs is switched off after half hour, heat measurement is taken again. This process is repeated until all rows of bulbs are switched off. Then the pipe is changed to the next diameter. Same process is continued until we obtain all the measurements.

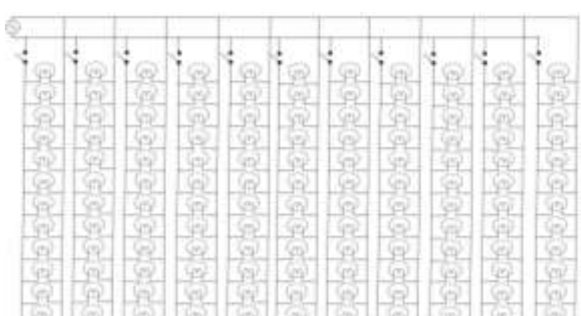

Figure 6: Schematic layout of 132 incandescent bulbs connected in 11 columns and 12 bulbs per column.

RESULTS AND DISCUSSION

The experiment results are shown in Table 1. Each bulb is 100 W. Total 12 incandescent bulbs are connected within one row. Total 11 rows are formed for testing purpose. Each time when switch on one circuit the load will increase by 5A. This validates Ohm's law.

Figure 7: All 132 bulbs are lit up

Table 1: Heat measurement (eddy current loss plus joule heating) versus pipe diameter and current in Cu conductor.

Pipe #	Pipe diameter (cm)	# of circuits (of 12 bulbs each) switched on:										
		1	2	3	4	5	6	7	8	9	10	11
		Measured currrent:										
		5	10	15	20	25	30	35	40	45	50	55
		Measured temperature (˚C):										
1	2.18	31.0	31.1	31.5	33.4	34.7	36.6	37.6	40.8	42.7	44.3	47.4
2	2.66	29.3	30.2	29.1	29.7	34.7	35.2	37.3	39.5	39.3	41.4	40.0
3	3.37	29.1	29.1	29.7	30.1	31.3	31.8	32.3	33.8	34.6	35.7	35.7
4	4.23	29.3	30.5	31.2	31.6	32.7	33.1	33.6	34.4	35.5	35.9	37.8
5	4.84	27.1	27.2	27.2	28.6	28.6	31.2	31.9	32.2	31.0	32.0	33.3
6	6.06	28.2	29.1	29.6	30.3	31.1	31.5	31.7	32.9	33.7	34.4	35.5
7	7.56	29.0	28.6	29.4	29.9	30.0	30.2	30.2	30.5	30.6	31.0	32.3
8	8.81	26.9	27.5	27.4	27.3	27.7	28.3	29.6	29.6	30.2	30.5	30.8

The overall measurements also validates the process control of the manufacturer of bulb in rating the 100W bulb truthfully. Table 1 is the temperature on the pipe. Ambient temperature is 29-31°C. Some of the measurement are even as low as 26.9°C because carbon steel pipes are normally cooler than the ambient temperature. All the data above ambient or 31°C is highlighted in yellow to red. One set of data for a single pipe takes approximately 6 hours with heat data taken every half hour. It can be noted that even for 55A current in the Cu conductor, the Ø=8.81 cm carbon steel pipe has no temperature rise above ambient.

Table 2: The regression analysis figures obtained through excel. The coefficients values used to extrapolate for different set of temperatures.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.85903793
R Square	0.737946166
Adjusted R Square	0.731780193
Standard Error	2.116070864
Observations	88

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1071.799385	535.8996923	119.6804167	1.91248E-25
Residual	85	380.6092517	4.477755903		
Total	87	1452.408636			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	32.51601774	0.701419101	46.35747398	4.05809E-62	31.12140865	33.91062683	31.12140865	33.91062683
diameter	-1.04660965	0.102314263	-10.22936212	1.77582E-16	-1.250037816	-0.843181484	-1.250037816	-0.843181484
Current	0.165590909	0.014266547	11.6069369	3.23474E-19	0.137225192	0.193956626	0.137225192	0.193956626

Based on the data obtained an equation can be derived to predict the future value of temperature for higher current.

T = B + B1 (d) + B2 (A)

T = Temperature (°C)
d = Diameter (cm)
A = Current (A)

		Coefficients
B	Intercept	32.516
B1	diameter	-1.046
B2	Current	0.165

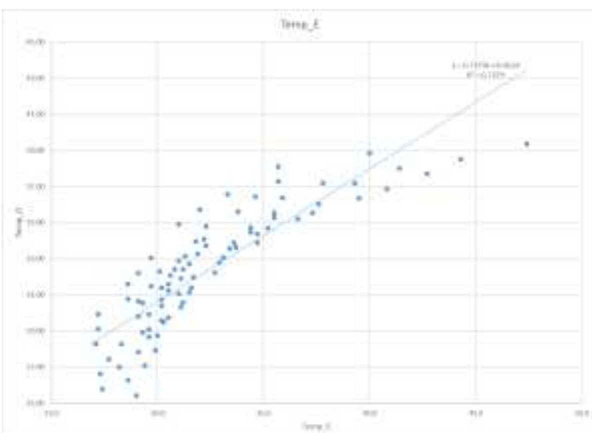

Figure 7: Theoretical temperature versus actual temperature plot by using the T=B+B1(d)+B2(A) equation.

A horizontal linear extrapolation of the data shows if 546A is transmitted within the Ø = 8.81 cm pipe the temperature of the pipe would reach 101.6 °C.

CONCLUSION

The overall objective of this research was to understand the losses suspending a conductor within a pipe which is used in the O&G industry.

The general conclusion obtained from the experiment is that when the spacing between the conductor and the pipe is increased the eddy current losses are observed to be lower. Heat measurement on the pipe used as a measure of the eddy current together with joule heating loss. At 1000kV the 500mm^2 cable which can handle 546A provides a power transfer of 546 X 1000 =546 MW for AC.

The results conclude that it is not possible to create an O/H condition in a GIL type technology for 630 km distance. The cable itself is half a diameter of the pipe from the ground. It is different compared to the very high elevated O/H lines. This short distance from the ground has a higher shunt susceptance causing higher leakage of AC electricity from the cable to the ground than O/H lines. The solution in eliminating shunt susceptance is to use DC. This type of DC transmission is proven in many parts of the world. With the combination of GIL technology and latest O&G pipe laying experience, it is possible to use HVDC to transmit electricity over long distance [6].

This research validates that setting up a bare transmission line in a submarine pipe is not only feasible but the energy loss is surprisingly low. The recently built Pengerang Power Station cost $1.2 billion and produces 1220 MW but it will continuously consume gas for 24 hours a day everyday. This proposed design provides free clean energy which can attract investment to build factories from all over the world. This means sharing the excess hydroelectric energy from Sarawak to Peninsular Malaysia over 630km transmission line.

This research finally concludes that bare conductor can handle the required current and N2 is flown to dissipate the heat. The optimum design as per Industry Experts will be using HDPE pipe. Further work can be carried out to pursue this experiment with different type of material.

ACKNOWLEDGMENT

This research is supported by UCTS (University College of Technology Sarawak) Research Grant, Ref. UCTS/RESEARCH/4/2017/14. Thanks to Ir Dr. Prashobh for sharing his vast theoretical and hands-on knowledge in electrical field.

REFERENCES

[1] Karunakaran, P., Osman, M. S., Lau, A. K., Lee, M. D., & Kumar, P. (2017, September). Underwater Electricity Transmission using Electric Cables Suspended within Carbon Steel Pipes. In 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC) (pp. 1247-1253). IEEE.

[2] Aliyu, S., & Garba, M. M. (2019). Review on Current Global Geothermal Energy Potentials and the Future Prospects.

[3] Shintani, T., Yamamoto, M., & Chen, M. T. (2011). Paleoenvironmental changes in the northern South China Sea over the past 28,000 years: a study of TEX86-derived sea surface temperatures and terrestrial biomarkers. Journal of Asian Earth Sciences, 40(6), 1221-1229.

[4] Koch, H. (2011). Gas insulated transmission lines (GIL). John Wiley & Sons.

[5] Gençolu, M. T. (2007). The comparison of ceramic and non-ceramic insulators. Engineering Sciences, 2(4), 274-294.

[6] Kalair, A., Abas, N., & Khan, N. (2016). Comparative study of HVAC and HVDC transmission systems. Renewable and Sustainable Energy Reviews, 59, 1653-1675.