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Technical Issues of a Water Supply Project for Abit Village, Sarawak, Malaysia

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***Abstract* - Worldwide 14 % of humanity has a severe lack of water and two billion have inadequate water supply. Most water supply problems are due to a lack of technology or vendors charging too much for the government to afford. This research enabled 36 homes of the Abit village to have water piped to their homes utilizing two 4 HP pumps, one to push up the water from the river, 400m horizontally and 14m vertically up to a 9000L holding tank and another to push it to each of the 36 homes via Ø=1" pipes. This project started in 2018, provided continuous water supply to Abit village for two years before a social problem of one villager requested the pump be moved. But it took a year to get it to work perfectly. Two months out of that one year was to wait out a flooding season. Many villagers, even young youths helped in the project on weekends and hopefully these youths were inspired to venture into electrical and mechanical engineering in future. Without water, even growing vegetables was not possible, now this and even small industries can be set up; positively lighting up the human spirit of the villagers.**

Keywords - water supply system, 3Φ phase pumps, HDPE pipe, HDPE tank, social problems, farming, small industries

I. INTRODUCTION

There are technologies developed to harvest water supply especially for areas where the government has not gotten the budget to supply it. This paper described one that uses an induction motor powered pump to suck-up river water and send it 400m horizontally and 14m vertically. This research started in 2018 and carried on till 2023. Three papers have been published about the project. This paper explains the details of the activities done in 2022 And 2023 for the project. Other than the physical benefit of getting water supply for drinking and bathing right to each village home, it enables farming of vegetables and most importantly a gratitude for humanity by the people of the village. Youths of 10 years to 15 were helping in troubleshooting the project. Hopefully this experience in electrical and mechanical engineering will lead them to be engineers in these fields in the future. Since this author was going to the village since 2018, some very young children who were helping a little have become strong youths and continue to help with much more responsible activities in the water supply project. But a main center of knowledge lies with a village person shown in Fig. 3 right image (the person wearing the red shirt).

The system used was to place a 4 HP pump at the riverbed and pump the water to a 9000L holding tank located 400m away horizontally and about 14m vertically above. For a period of about two years the Abit village was having water supply from the designed and built system, then a problem cropped up. It was not technical but of all things, a moral issue of one family which claimed the land on which the 4 HP pump was placed by the riverbank; that is just a surface area of 1702mm X 851mm (67" X 34"). They suddenly said the rest of the village has two weeks to vacate the pump. Since the beginning of the village about 100 years ago all villagers walked a distance to this home, went behind it and down a steep slope of 30' to this riverbank to get water in buckets during the dry season. This point has the largest surface area of the river around the village where the width can reach about 30'. During the wet season all homes harvest the water falling on their roof, by funneling the roof gutter to a big blue HDPE (high density polyethylene) tank.

Due to the claim by that one homeowner, over one Saturday, the village head organized a service activity to move the 4 HP pump and Ø=2" HDPE pipe over one kilometer away. Two weeks prior to that Saturday, the villagers used their long knives to cut through the vegetation to reach the river. That point of the river has only a small surface area with the widest width being only about 10'.

When performing an engineering project, one must understand the historical context of the people being served and why they have certain attitudes. These villagers are of the Iban race of Sarawak. They were historically known to be fighters and have chased other races up mountains [1]. The Sarawak State of Malaysia was not originally colonized by the British like the rest of Malaysia. It was a particular Englishman named

James Brooke who decided to make it his Kingdom [2]. Obviously, he needed to appease the most martial race of Sarawak who were the Ibans. And just as was the colonist policy around the world of dealing with martial races, alcohol was given to the villagers initially at cheap rates and later once they got addicted, they paid the normal rate [3]. Using this policy, the Iban race was made the highest consumer of alcohol among the races in Sarawak, Malaysia. But of course, the educated Ibans in the cities have begun to see this ploy of Europeans and have started to be very progressive. In fact, when this author was working in a factory, he saw the Iban workers having a big alcohol consumption event at the end of each shift cycle. He would chide them for it, but they would rely that they were always a race that drank alcohol. But the Europeans had been running this land since 1835 which would create many generations of alcohol drinkers [4]. The same technique was done for the Native Americans, the Aborigines of Australia [5], the Māori of New Zealand [6], and the Blacks in South Africa [7].

This author studied for six years (Bachelors and Masters) in South Dakota, USA where the Missouri River cuts the state vertically in half and the western half is Native American reservation, especially from the Sioux tribe. The Sioux, like the Ibans, were intense warriors with their most famous victory led by Sitting Bull who defeated the Union army led by George Armstrong Custer in the Battle of Little Bighorn [8]. But by 1987-1993 (six years) when this author was there, the Sioux had become one of the biggest alcohol addicts in the world. Native Americans can walk into the main university of the state, South Dakota State University (SDSU), where this author studied and take any course for free. But there were only six Native Americans in the university, all taking drawing courses. One ended up in electrical engineering after serving for the USA military, but he must drink from a big case of Budweiser beer continuously even in class and everywhere he walks around the university; he lasted for three months in SDSU. Incidentally his closest friends are the Indians students from Malaysia and India. In the 1980s and 1990s, the Native Americans were given an allowance of USD2000/month and most lost it in substance abuse within half a month. Comparatively this author worked to earn USD200/month which enabled him to purchase food, rent and books to be in university.

About five km from Abit there is a hardware store where the male helpers of the store looked stoned with substance abuse. It must be something like substance abuse for a village homeowner to be so inhuman as to refuse water supply to an entire village of 180 people.

This village is particularly dry, and the villagers have a statement, “There is an umbrella above our village.” They reported to this author that they cannot even grow vegetables because the rainwater is not consistent and therefore their efforts of growing vegetables will go to waste as the vegetable dies. Every Iban male seems to compulsorily have a long knife (called “parang”), probably from their warrior days. But even to engage in small industries like knife making in this village is not practical without a supply of water. Therefore, the only ones employed work in the oil palm plantations in nearby areas, either as labor or as private transporters of oil palm fruits to mills; the Toyota Hilux being the main tool they utilize for this.

II. LITERATURE REVIEW

Three publications were previously made on the reasons for this particular design for the water supply system for this village after much trial and error [9][10][11]. This author and team had no previous experience with water pumps. Trial and error of building and rebuilding many times resulted in the final system, shown in Fig. 4 with the source of water which is a one-way valve below the blue floats and the 4 HP pump nearby sucking up water and pushing it 400m horizontally and 14 m vertically [10]. The initial system was built in a school in the city of Kuching prior to being brought to the village which is a two-hour drive away. Building it up in the village is not practical because even if a small screw is missing a four-hour drive (to and fro) must be made [11]. Initially similar systems were studied worldwide there are many initiatives in water harvesting, notably in India and these were studied to come up with an optimum solution [12][13][14].

The main deterrent for the government in providing water supply to all villagers is the cost. This project to provide water supply to Abit was accomplished with two grants with a total value of MYR45,000=USD9956. But the effort put in by this author plus three final year project (FYP) students from his university plus his three engineering student children and the villagers was quite enormous and can easily put the actual value of the effort in design, buildup trial and effort to be worth around a million USD. Much of the problem is not getting material to get the job done, it includes dealing with the local electrical authority (LEA), which took a whole year. The village had three Φ power in the overhead lines but only single Φ comes down to each home and even the larger Community Hall, behind which is located the Pump House as shown in Fig. 5 right image.

III. METHODOLOGY

Details of how the water supply system was designed and built were previously described in three previous publications. One of the biggest methods that enabled the success of building this system with a budget of only USD9956 was using normal 2.5mm^2 Φ wires enclosed in HDPE pipes. The manufacturer of these HDPE pipes is located in Kuching and they put a blue line longitudinally along the pipe for water pipes and a red line to indicate it is an electrical conduit. But the manager said both pipes are made with the same process i.e. there is no difference in the blue lined or red lined pipe. Any electrical contractors in Malaysia will insist that underground (U/G) cables must be used when the wires need to be laid in the environment, especially where some portions are within the river water. But the cost of underground cable is terribly expensive. The cheapest U/G cost (4 core since they don’t sell 3 core) is USD5:

1m – USD5
Therefore 400m- USD5 X 400 =USD2000
Add USD500 for freight.
Three cable joints since they come as 100m lengths:
USD222 X 3 = USD666
Total cost = USD(2000+500+666) = USD3166
USD(3166/9956(total budget)) X 100%=32%

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Therefore, the U/G cable itself would cost 32% of the entire research grant for this project. Therefore the 2.5mm^2 Φ wires, L1, L2 and L3 were run within Ø = 1" HDPE water pipes joined with Ø = 1" HDPE fittings. The price of one roll of 100m Ø=1" HDPE pipes = MYR210
4 rolls needed = MYR210 X 4 = MYR840
100m of 2.5mm^2 wires = MYR85
4 rolls needed per Φ = MYR85 X 4 = MYR340
Total cost = MYR840 + MYR340 = MYR1180
Add cost of soldering and taping each joint including tools = MYR150
Total cost =MYR(840 + 340 + 150) = MYR1330 = USD296
Therefore, the cost of the wiring reduced from USD2666 to USD296 which is:
296/3166 X 100 = 9%
Therefore, the wires in HDPE pipes cost only 9% compared to using U/G cables.

The cable joints were made using a butane flamer as shown in Fig. 9 right image. This is the optimum method. Fig. 9 was done in a lab and not at the site; it is not convenient to carry a camera to the site since it may get wet. Bringing a camera to the site must be a dedicated task and not lumped up with bringing other tools which can survive being soaked.

For joints, most electrical contractors use a copper tube that surrounds both ends of the wires and crimps it. This is wrong; mechanical engineers are taught that when a metal is stressed, it needs to be annealed. For example, when a car company stamps a sheet of steel to become a car hood, they must then anneal it at 500°C for 24 hours, this is to relieve the stress within the atoms especially at the portions that are severely deformed. With crimping, there is no annealing and actually the annealing will melt the PVC surrounding the wire and cause copper oxide formation between the copper tune and the copper wire and all oxides of metals are insulators. Actually, metal oxides like magnesium oxide are some of the best insulators in the industry. Without annealing such joints are brittle and will break. Imagine a wire going up five stories and a crimped joint is made, that is quite a lot of weight pulling on the joint. If it breaks, it is alright, an electrician can be called to repair the problem, but if it is partially broken, the surface area through which electrons can flow is much smaller and will not be able to carry load current. In such cases there will be heat buildup or even worse arching, which is very powerful and like welding, which can cause a short circuit. In short circuits L and N wires touch. Since V=IR and I=V/R where R of copper is about R= 0.02 Ω (estimate), therefore I will shoot up to a very high value of:

$$I = \frac{V}{R} = \frac{240}{0.02} = 12{,}000A\ .$$

Most electrical fires of buildings are due to this.

The method used for joining wires in the Abit village is to first strip PVC insulation of 2.5mm^2 wire for about 3" on both ends. Then a plier is used to twist the wire very tightly. Then the flamer is used to blow the end of the twisted joint. A piece of solder of about 2' is cut off from the roll of solder and this is slowly brought down on the heated twisted wire till it is completely covered with solder. The experience showed that it is not ergonomic to hold the whole roll of solder in the hand. Ergonomics is very important because the flamer is extremely hot. This author has an experience of the flame accidentally moving over the skin of his hand for just milliseconds and it was immediately burnt (marks lasting a few weeks). This soldered joint is then let to cool down and then the end (which was flamed) is cut off since it is sharp and may cut through the insulation tape. The twisted section is bent to be parallel with the wire. Then insulation tape (3M brand) is used to insulate the joint. Only 3M tape must be used because in the experience of this author and many senior contractors, it is the best value for money. Some other brands may even be more expensive, but the glue is not sticky enough. The reputation of 3M is such that the LEA uses a box of 3M material to do high voltage U/G cable joints up to 33kV. The flamer must blow only the end of the twisted joint because once it is flamed, it becomes copper oxide and solder does not stick to copper oxide. Note copper is one of the most colorful elements, which initially turn from golden to orange upon oxidation and eventually black and later green as for the Statue of Liberty of the USA, after sulfur enters it. Artists of old used copper plates and heated it variously to make copper pictures. The stripped two ends of the wire must be twisted tightly because solder must not enter in-between the copper wire. This is because Cu is the number two conductor while solder is made of tin (60%) and lead (40%). Tin is the number 11 conductor and lead is the number 13 conductor.

Initially at the new location, the 4 HP pump was placed at a spot where the villagers stated is higher than the highest tide of the river. But after this author left, they feedback that whenever they switched off the pump, it needed to be primed again with a combustion engine pump. Priming is down as shown in Fig. 1. The combustion engine pump is shown in Fig. 2 third image (the red color one) will provide high pressure water which is poured using the orange garden hose into the priming hole after opening the #24 stainless-steel bolt. Once priming is done as indicated by high pressure water (4 HP) coming out of the Ø=2" HDPE fitting, the stainless-steel bolt is screwed back into the priming hole. While priming, occasionally the pressure will be good in the Ø=2" HDPE fitting, and when that happens, it is too painful for a human hand to hold the orange garden hose at the priming hole. Therefore 2.5mm^2 wire (green in Fig. 1) and a vice grip plier method as shown in Fig. 1 was used to hold the garden hose at the priming hole.

The complaint of the villagers was that the pump must be primed each time to get water to flow to the 9000L holding tank. Three root causes were suspected for this issue:

1) The intake which was about 150m away was too far for the pump to suck up the water from the river
2) The one-way valve at the intake within the river was not working (the one-way valve is shown in Fig. 3 right image).
3) The pump was clogged with mud.

All three were worked upon. More wires were purchased to place the 4 HP pump next to the intake. A new one-way valve was purchased, and the pump was removed and opened. One may think it is inefficient to get parts for all three activities and not try them out one by one, but to reach the pump after wading through the river water is quite an energy consuming task. To

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get parts from the car one needs to climb up vertically about 14m which will get even villagers in their 20s to be panting heavily. It also takes two hours (four hours for two ways) to reach the village) from the city of Kuching. But after performing all three tasks, the eventual solution proved to be bringing the pump next to the intake. This was the last activity performed because this author was unsure if the 4 HP pump placed on two floats would really float. But over a two-month period work could not be carried out because the villagers feedback that the pump was floating on its floats on water during an exceptionally wet season not seen in 20 years which happened in the beginning of 2023.

At the new location the intake system is depicted in Fig. 4. On the right are the two used chemical tanks (floats) joined together, under which is the intake one-way valve (shown in Fig. 3 right image). On the left is the 4 HP pump which is also on two floats.

Fig. 4 left image depicts the bags which need to be used to bring the tools to the site. The blue and black bags were used to carry the tools and the cylindrical plastic at the bottom was used to bring long screwdrivers. The entire pump had to be taken apart at this site because previously when the pump was brought to Kuching for servicing, one part was not installed back. It must be noted that one must wade through river water that can reach one's abdomen to reach the site; this pathway is shown in Fig. 5 left image. Thereby falling with the tool bag is a possibility because one cannot see the bottom of the river through the murky water and there are various spots which can be unexpectedly deep. A fall into the vegetation can be painful as it is covered with a plant which has three feet long leaves with thorns surrounding the entire surrounding of the leaf. These thorns will cut hands and human body parts like serrated knives. After many cuts and bruises on hands, legs and even head, a method was devised to walk through the river, which is to hold a 5' strong stick (as a walking stick) and wear gloves. Having that stick is similar to a person holding a long horizontal stick when walking on a tightrope, it doesn't take much force to get back balance, a light touch on the 5' stick will give back balance from a situation of almost falling; this could be psychological.

A water boot must be worn though it will be filled with water during the journey because water level can reach abdomen level. The one used by this author has a very good grip to hold on to the slippery mud of the riverbed and is also a steel-toed safety shoe. The pathway back to the Pump House is shown in Fig. 5 left image and the Pump House itself is shown in Fig. 5 right image. The Pump House is horizontally 400m from the pump and vertically 14m up.

The three tools carried to and fro the site which cannot get wet are the multimeter, a Fluke volt alert and a walkie talkie as shown in Fig. 7. The multimeter was brought to measure the voltage drop since the 4 HP pump is 200 m away from the control panel. There was no voltage drop because the current in each phase is < 3A and 2.5 mm^2 wire has a current carrying capacity of 21A. A Walkie Talkie is necessary in all rural jobs where there is no phone signal. Once the repair of the pump was done, the Walkie Talkie was used to ask the person standing by in the Pump House to switch on the pump. Of course, that person must also ensure nobody inadvertently switches on the 3 Φ power while wiring work is being carried out at the 4 HP pump.

The third image of Fig. 2 is the red combustion engine pump which is used to prime the 4 HP pump. This pump plus the tools depicted as the other images of Fig. 2 were given to the villagers. These tools will enable the complete opening up of the pump and repairing any Ø=2" HDPE pipe leaks. On the very left of Fig. 2 is a pipe cutter. The black knob is turned clockwise slowly as the whole red tool is wound around the Ø = 2" HDPE pipe. The middle image is two pipe wrenches to open the pipe fittings; two is needed because as one is turned, the other must be held in place. The leftmost image is wrench number 8, 13, 22/24 and a long nose vice grip plier.

For the 4 HP pump, the current per phase can be calculated as:

$$4HP = 4X746 = 2984W$$

$$P = \sqrt{3}VIcos\Theta = 2984W = \sqrt{3}X415XIX0.8$$

$$I_L = \frac{2984}{\sqrt{3}X415X0.8} = 5.189A \Rightarrow I_P = \frac{5.189}{\sqrt{3}} \approx 3A$$

The measured value is about 2.5-2.8A.
The voltage and current at the pump are shown in Table 1.

Table 1: The voltage and current at the 4 HP pump at the site

	Voltage (V)	Current (A)
R-Star point	238.1	
Y-Star point	238.5	
B-Star point	238.3	
RY	409.9	
RB	410.1	
YB	410.2	
R		2.7
Y		2.5
B		2.8
Pump	Multistage centrifugal pumps with vertical axis DAB KVC 70/120T , 4HP Conn in 1 1/4 ", Conn out 1 1/4", Max height 94m	

As can be seen in Fig. 8 the connection at the motor is Star and not Delta. This provides 240V to each stator coil of the 4 HP induction motor. Using a Delta connection will provide 415V to each stator coil of the motor. The manufacturer recommended a Star connection for this motor.

The pump used is a multistage centrifugal pump as shown in Fig. 6. The advantage of such pumps compared to single stage ones are that multiple impellers are mounted on one shaft.

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The one installed in Abit has seven impellers as shown in Fig. 6 left image. With every impeller added there is minimal energy loss but enabling a much higher pressure. Multistage pumps also have a tighter clearance space, smaller impeller diameter (thereby more durable) and a smaller motor. The noise level emitted by such pumps is also much lower.

Before going to the village to do any task for the pump system, proper planning of the task to be carried out must be done as shown in Fig. 9 left image. All tools, and accessories (screws, tapes etc.) needed must be imagined and determined. There is no option of purchasing anything missing at the site. This is like sending a spaceship to outer space; every single detail of the task must be worked out.

Fig. 10 is the control circuitry for the system. Fig. 11 is the single line diagram for the overall power supply circuit. Fig. 12 is the power circuit used to start the pump of the 4 HP, 3 Φ pump. Fig. 12 is the power side of the starter circuit used. The starter circuit utilizes three contactors which are given names Line (L), Transformer (T) and Star (S). Initially T and S closes providing energy to the autotransformer and L is open. With the autotransformer energized, there will be energy at its tap which is at 70% of the number of coils in the autotran. Current from this tap will go to the induction motor with a voltage of:

$$240V\ X\ \frac{70}{100} = 168V$$

Therefore, R Φ 168V goes to one side of one motor coil, the other side of the coil is a Star point which is at 0V. Fig. 13 explains why joining all three Φ wires will result in V=0V at the Star point.

Therefore, each of the three induction motor coils will have a voltage of 168V. The timer is set to 6 s, after which T and S contactors will open and L will close. Now the full line voltage of 240V will go to one side of each coil with the other side still at Star point and thereby having 0V This will energize each of the three coils with 240V.

Fig. 14 is the wiring schematic for the control circuit. The control circuit taps power from one of the phases. In this case from the R Φ. The power will pass the MCB (miniature circuit breaker) which is represented in the schematic as a fuse. It will go down to T3 (one of the contact points of T contactor) and also the O/L (overload relay). Out of the O/L, current will pass the Stop switch which is normally closed (NC) and then be at one side of the normally open (NO) Start switch. Current will also go to one side of the T3 and L4. When the Start button is pressed, current will flow pass t2 (timer contact) and pass L2 to energize the coil of the S contactor. Energizing a coil of a contactor will cause switches within that contactor to be opposite of whatever is shown in the schematic. Therefore, S1 will be closed so current will flow through it pass L3 to energize the coil of T contactor and timer coil (small t represents timer and big T represents the transformer contactor). Therefore, current can now pass through T2 and L4, which are holding circuits for the Start button. The Start button has a spring return so will go back to the open position after being pushed. But even if it is open now, current can flow to the rest of the right circuit because it can flow through T2 and L4. Similarly, the T coil will remain energized due to the holding circuit T1. After 6 s, S coil will de-energize causing S1 to open and since t coil was also energized, current will flow through t2 through D2 which has now closed to energize the coil in L contactor. When the L coil is energized, L2 and L3 will open thereby de-energizing S, T contactors plus the coil in the timer. From now on only the L contactor will be energized providing full incoming power to the induction motor. Fig. 15 is the 4 HP 3 Φ pump which will push water from the 9000L holding tank to each of the homes of the village.

Fig. 1: Priming the 4 HP pump

Fig. 2: Tools given to the villagers

Fig. 3: The left image shows the blue and black bags that were used to carry the tools and the cylindrical black plastic at the bottom was used to bring long screwdrivers. The right image is the one way valve is the intake point within the river

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Fig. 4: On the right are the two holding tanks joined together, under which is the intake one-way valve. On the left is the 4 HP pump also on two floats.

Fig. 5: The right image is the pathway back to the Pump House. On the right is the HDPE pipe carrying the 3Φ wires of 2.5mm^2 each. Below it is the Ø=2" pipe carrying the water. The other pipes are not used. The right image shows the Pump House where the 9000L holding tank, the red Pressure Tank, the left for the incoming and the right is above the outgoing 4HP pump (black color)

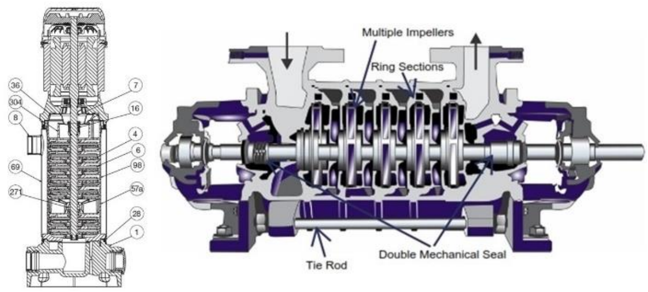

Fig. 6: Multistage centrifugal pumps. The one used in Abit is on the left with seven impellers

Fig. 7: The three equipment brought to site which cannot get wet

Fig. 8: The phase to star point voltage is V=238V and the Φ -Φ voltage is 409.9V.

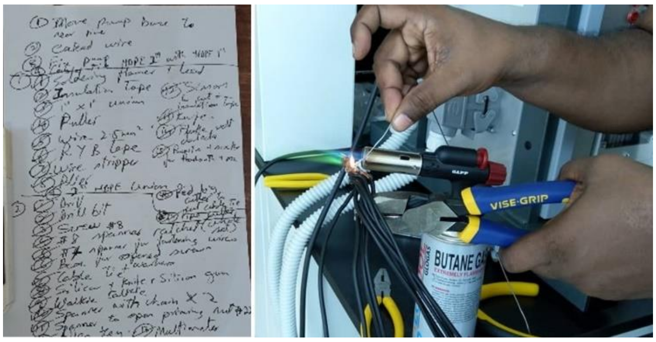

Fig. 9: The right image is the planning list that needs to be made prior to each trip to Abit village. The left image is the Flamer cable joint being performed.

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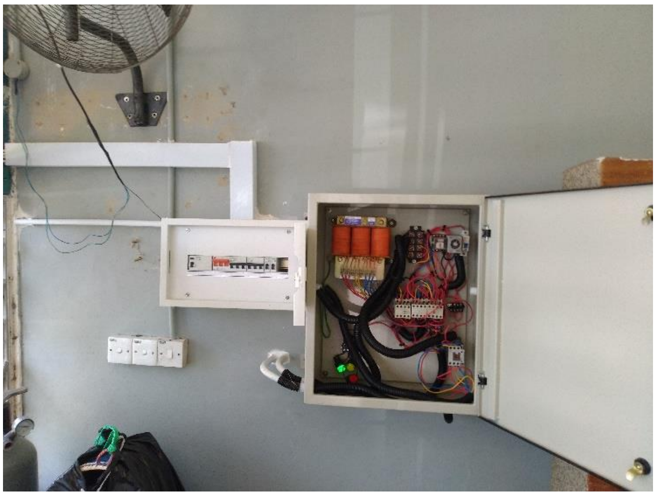

Fig. 10: The starter circuit for the 4 HP 3 Φ motor

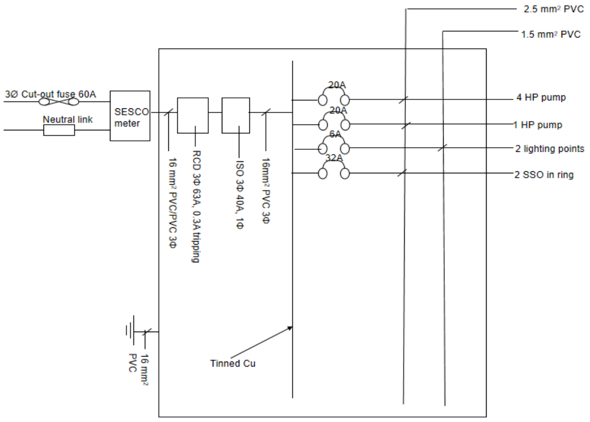

Fig. 11: The single line schematic for the overall power supply

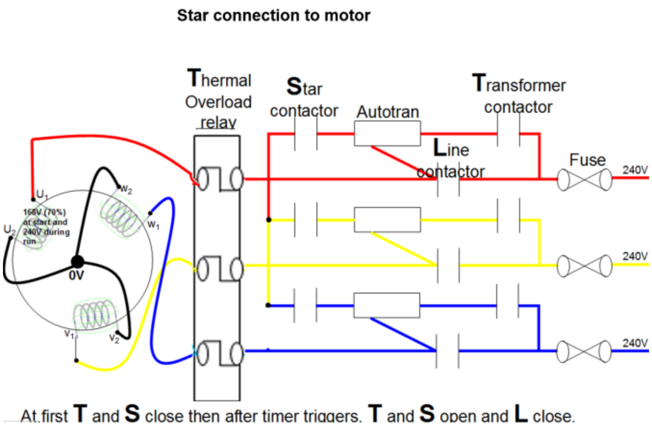

Fig. 12: The power circuit for the 4 HP 3Φ motor of the pump

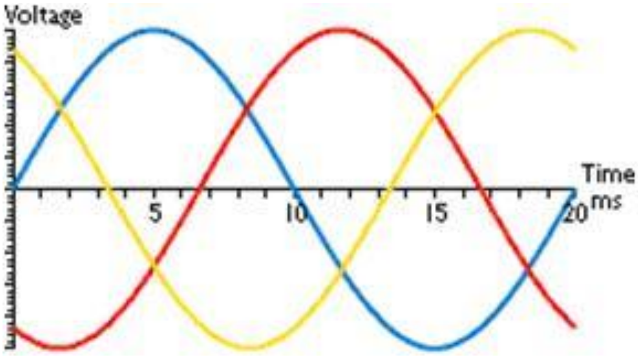

Fig. 13: Why a Star point has 0V. Looking at 5ms, say B Φ = 1, Y Φ = - ½ so joining the R, Y, B Φ will result in 1- ½ - ½ = 0V. The same is the case at all moments of time on the X-axis.

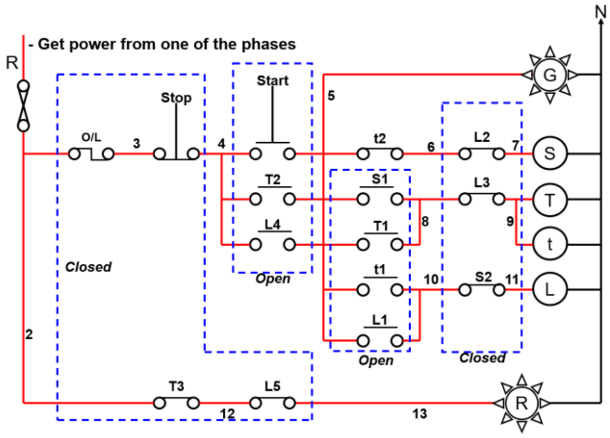

Fig. 14: The control circuit for the 4HP 3Φ motor of the pump

Fig. 15: The outgoing 4 HP pump to pump water from the 9000L holding tank to each home of the village

IV. ACKNOWLEDGEMENT

This research was done with a research grant from University of Technology Sarawak (UTS) with the value of USD9,956.

V. CONCLUSION

The project successfully enabled 36 homes of Abit village to have water supply straight to their homes. Two pumps were

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used, one to suck up water from the river and send it up horizontally 400m and vertically 14 m to a 9000 L holding tank. From this tank another 4 HP pump pumps the water to 1.5" HDPE pipes to all 36 homes. Three suspected causes were predicted of needing to prime the pump each time to get it to work and the conclusion was if the pump is as close to the intake as possible, it works very well. With the system working again, the villagers can start growing vegetables again and probably even small industries in the village. Various innovative techniques were also described in this paper to solve technical problems in the building of the system. There is a good chance the young youths who started helping in this project when they were 10 years old (helping a little in-between their football games) and today 15 will eventually take up electrical and mechanical engineering subjects.

VI. REFERENCE

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