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Analysis of Power and Voltage Losses in Electric Submersible Pump Motor Installations

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Abstract — In area mining are quite extreme, where the level of safety from high temperatures and toxic gases which are explosive as well as well flow pressure is also high and can damage production equipment. Therefore, it is very necessary to install reliable electrical power, starting from analyzing the selection of cable types that used, voltage drop, power losses and transformer selection. The problems mentioned previously, this research carried out an analysis of improvements to voltage drops and power losses that occurred in the ESP motor installation system. The method used is to replace the type of cable used in three scenarios with three different types of cable. The installation system data obtained from this company was then processed using software which was then validated with theoretical calculation results. The result of voltage drops and power losses in ESP cables according to standards using scenario 3, replacing AWG #2/0 type with a voltage rating of 5 kV, diameter of 11.709 mm and has a KHA of up to 210 A. The voltage drop value after repairs are carried out based on theoretical calculation results has an average percentage index value of 4.5% and power losses of 4.6%. This shows that in the condition after repairs, both the results of simulation calculations and theoretical values have met the IEEE std 141-1993 standard which states that the value of voltage drop and power losses in industrial plan distribution systems must be below 5%.

Keywords: ESP, Power Losses, Voltage Drop.

INTRODUCTION

Crude oil production can be done in two ways, namely the natural flow method and the artificial lift method [1]. In the natural flow method, an oil well will flow by itself (without any assistance) to the surface as long as the energy in the reservoir is still strong enough to push the fluid in the well and flow it to the process facility. Meanwhile, the artificial lift method is used if a well whose reservoir energy is no longer capable of producing oil using the natural burst method. One suitable artificial lifting method is to use an Electric Submersible Pump (ESP) [2], [3]. The choice of artificial lifting method with ESP is of course based on technical and economic considerations. Where there are several types of artificial lifting, including pumping jack, jet pump, and mono pump. The electric submersible pump lifting method has its own advantages. Can be used for wells with a depth of around ±15000ft. This ESP pump is installed vertically in an oil production well and all components of this pump are immersed in the well fluid. This pump is a multilevel centrifugal pump, with each level having an impeller and diffuser. Fluid that enters through the pump intake will go to the first level of the pump. The rotation of

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the impeller will provide a pushing force to the fluid, so that the fluid will have greater energy than before and the diffuser will direct the fluid to the impeller, then the process will repeat until it reaches the last level of the ESP pump [4]. The artificial lifting method using an Electric Submersible Pump (ESP), reliable electrical power installation is required, starting from analyzing the selection of the type of cable used, voltage drop, power losses to selecting the transformer used. Because the mining area is quite extreme, where the level of safety from high temperatures and explosive toxic gases and well flow pressure is also high and can damage production components or equipment. Therefore, the installation of electrical power and protection on ESP motors in mining areas is slightly different from motor installations in general [5]. Based on the background above, researchers are interested in compiling research with the title "Analysis of Power and Voltage Losses in Electrical Submersible Pump (ESP) Motor Installations". In order to be able to identify and improve the Electric Submersible Pump (ESP) motor installation system in accordance with the working principles of the desired system and the average oil production to be achieved remains optimal.

A. ESP Cable Selection

Three-phase electric power is supplied from the surface to the electric motor via three ESP cables. The cable used is a special cable for ESP motors or REDA cable. One of the things you need to pay attention to when choosing an ESP cable is whether a cable's Current Carrying Capacity (CCC) is suitable for carrying load current. Therefore, to find the CCC value of the cable, you can use an equation such as [6]:

$$KHA=125\%\ x\ I_n \tag{1}$$

Where KHA is the current carrying capacity (amperes); and I_n is the nominal load current.

In a three-phase AC electrical circuit, there is an impedance value that influences the occurrence of voltage drops and power losses. This impedance value is influenced by the resistive and inductive components of the conductor. Although in general the value of inductive reactance is lower, it should not be ignored. The following is the equation for calculating impedance values [7]:

$$Z=\sqrt{R^2+X_L{}^2} \tag{2}$$

Where Z is the total impedance (ohms); R is the specific resistance of the conductor at 75 (ohm/1000 m); and X_L is the inductive reactance at 60 Hz (ohm/1000 m).

The conductor of a cable can be affected by the temperature around which the cable is placed, where the cable is at the depth of the well and has a high temperature. Well temperature is always an inhibiting factor in implementing an ESP unit. Standard ESP equipment can be applied at a maximum temperature of around 240F. Above this limit, the average performance of the ESP Component quickly deteriorates and failure may eventually occur. One of the main effects of high temperatures is an increase in the electrical resistance of the conductor which causes an increase in voltage drop and power losses in the cable. When calculating voltage drop and power losses, one thing that must be considered is the temperature of the cable because the impedance of metal will increase as the temperature increases. The following is a general equation used to determine the cable impedance value at a certain temperature [7]:

$$Z_T=\frac{L_C\ \sqrt{R^2+X_L{}^2}}{1000}(1+0{,}00323\ (T\text{-}75)) \tag{3}$$

Where Z_T is the cable impedance at temperature T (ohm); L_C is the cable length (m); R is the specific resistance of the conductor at 75 (ohm/1000 m); X_L is the inductive reactance at 60 Hz (ohm/1000 m); and T is the cable temperature (℃).

B. Voltage Drop

Voltage drop is the amount of voltage lost in a conductor. The voltage drop on an electric power line is generally directly proportional to the length of the line and load and inversely proportional to the cross-sectional area of the conductor. Based on the IEEE standard std 141-1993, the allowable voltage drop in the distribution system for industrial plants is 5% of the voltage value distributed [8]. Practical equation in determining how much voltage drop occurs in the ESP motor power cable line. The cable used is influenced by the temperature of the well and the temperature of the cable carrying the electric current. The following is the equation used to calculate the voltage drop in cables with a three-phase system [7]:

$$\Delta V=\sqrt{3}\ x\ Z_T\ x\ I \quad (4)$$

Where; ΔV is the voltage drop (volts); Z_T is the cable impedance at temperature T (ohm); and I is the load current (amperes).

From equation (4), it can be seen the percentage value of voltage drop that occurs along the conductor using equation [9]:

$$\Delta V\%=\frac{\text{Voltage Drop}}{\text{Channeled Voltage}}x100\% \quad (5)$$

C. Power Losses

Power loss is the loss of electrical power due to resistance or resistance in the conductor. Power loss can also be interpreted as the difference between the power sent and the power received by the load (consumer). Practical equation for determining the amount of power losses that occur in the ESP motor power cable line. The cable used is influenced by the well temperature and cable temperature. The following is the equation used to calculate power losses in cables with a three-phase system [7]:

$$P_{Loss}=\frac{3\ x\ I^2\ x\ Z_T}{1000} \quad (6)$$

Where P_{Loss} are power losses (kW); I the current (amperes); and Z_T is the impedance of the cable at temperature *T* (ohm).

Then you can find out the percentage value of voltage drop that occurs along the conductor using equation [10]:

$$P_{Loss}\%=\frac{P_{Loss}}{\text{Distributed Power}}x100\% \quad (7)$$

D. Step-Up Transformator

A transformer is a device used to transform voltage level values from one value to another voltage value. The function of the transformer is to change the supply voltage value of the power plant into a voltage needed by the motor to be able to drive the pump system. Motors have different operating voltages, therefore the voltage from the source must first be adjusted to the motor's operating voltage before being supplied to the motor. Each ESP motor has a different voltage range depending on the type of motor. The transformer is selected based on the amount of KVA required by the motor. In determining the transformer that will be used in the system, you should know the voltage sources available on the distribution network in the field and the load voltage that must be supplied. The transformer is selected based on the amount of KVA required by the motor. To determine the capacity of the power transformer to be used, it can be calculated using the equation below [7]:

$$S = \frac{\sqrt{3} \times V_s \times I_m}{1000} \quad (8)$$

Where S is the apparent power capacity (KVA), V_s is the voltage (volt), and I_m is the full load current.

METHOD

A systematic sequence consisting of various stages in carrying out a thesis is called a research method. The research was conducted at Private Company, Meranti Islands Regency, Riau Province. To complete the problem formulation and achieve the research objectives in this thesis, data on the installation of the Electric Submersible Pump (ESP) motor on the AC 05 oil well is needed. The data used to fill in the parameters in the software was obtained from direct measurement results and interview results. with technicians in the field. In this thesis research, research was conducted using data on the ESP motor installation system on the AC 05 oil well at Private Company. The first step that must be taken in this research is to find a problem formulation, in this case, the problem formulation is how to calculate and repair the voltage drop and power losses that occur in the ESP motor installation system cable in AC oil wells 05. If the problem formulation has been formed, literature studies will be carried out from various sources such as books or journals. Next, the author will make direct observations over a certain period to obtain technical data on the ESP motor installation system at Private Company. Where this data will later be used for simulation modeling using software and theoretical calculations. Before carrying out the simulation, the author must first calculate and select the type of ESP cable used with the Current Carrying Ability parameters, and cable impedance value in normal conditions and at certain temperature conditions. After getting the cable type, continue by analyzing the voltage drop and power losses that occur in the ESP cable and see whether the voltage drop and power losses meet the IEEE std 141-1993 standard, namely below 5%. If the calculation results do not meet the standards, a repair scenario will be carried out by replacing the type of conductor or cable that has a larger cross-sectional area than the previous cable. This will be done repeatedly until the voltage drop and power losses are by the standards has been established. Then, as the final step, after obtaining the voltage drop and power loss values that are by the established standards, conclusions will be drawn.

Table 1. Data of AC Oil Well History 05 [11]

Water- Cut (WC)	99,00%
Oil Flow Rate (Qo)	28 BOPD
Total Flow Rate (Q1)	3169 BFPD
Water Specific Gravity (SGW)	1
Oil Specific Gravity (SGO)	0,878
Casing Pressure (CP)	120 Psi
Well Depth	5000 ft
Pump Setting Depth (PSD)	3700 ft
Temperature	250 °F

A. Single Line ESP Motor Installation

The ESP motor installation system used as a research object is in the form of a distribution channel starting from the generating system at Private Company. The AC 05 oil well at Private Company originates from a generator with a capacity of 2.8 MW with a voltage of 13.8 kV. Then, after the distribution system reaches the AC 05 oil well area, the voltage will be reduced to 480 V which will be used for the connecting device and ESP motor starting device. After that, the return voltage will be increased to 1500 V which will be used to start the ESP motor located in the AC 05 oil well with a channel length of 3800 ft or the equivalent of 1158 meters into the ground.

Table 2. Data of Bus Voltage Level AC Oil Well Installation 05 [11]

Name of The Bus	Voltage (kV)
Bus 1	13.8
Bus 2	0.48
Bus 3	0.48
Bus 4	0.48
Bus 5	1.5
Bus 6	1.5

Table 3. Data of Bus Voltage Level AC Oil Well Installation 05 [11]

No	Current (A)			Voltage F-F (V)	Power (kW)
	R	S	T		
1	77	77	75	1474	187
2	74	74	72	1477	181
3	76	76	74	1475	185
4	77	77	75	1474	187
5	74	76	76	1475	185
6	75	77	77	1474	187
7	77	77	75	1474	187
8	77	77	75	1474	187
9	76	76	74	1475	188
10	74	74	72	1477	181
11	74	74	72	1477	181
12	77	77	75	1474	187
13	72	74	74	1477	181
14	72	74	74	1477	181
15	74	74	72	1477	181
16	76	76	74	1475	185
17	77	77	75	1474	187
18	74	74	72	1477	181
19	77	77	75	1474	187
20	74	76	76	1475	185
21	74	74	72	1477	181
22	75	75	73	1476	183
23	75	75	74	1476	183
24	75	75	73	1476	183
25	77	77	75	1474	187
26	72	74	74	1477	181
27	72	74	74	1477	181
28	76	76	74	1475	185
29	77	77	75	1474	187
30	76	76	74	1475	185
31	76	76	74	1475	185

After all the data has been collected, technical data or equipment specifications are input into the ESP motor installation system simulation created using software. The following is a single line diagram modeling of the ESP motor installation system on the AC 05 oil well under normal conditions using software.

Table 4. Data of AC Oil Well Distribution Transformer Data 05 [11]

Transformer	Capasity (kVA)	Voltage (kV)		Impedance
		Primary	Secondary	
Step Down	1250	13.8	0.48	5.5
Step Up	350	0.48	1.5	4

Table 5. ESP Pump Specifications [11]

Merk	EJP
Series	540
Shaft Size	7/8
Type	ING –2500
Flow	1800 – 3100 bbl/D
Amount of Stages	118
HP / STAGES	1213
HD / STAGES	42.63

Table 6. ESP Motor Specifications [11]

S/N	550 -3118
TYPE	62 D 540S
VOLT	1475
AMPS	97
HP	225
CONN	Y
HERTZ	60
RPM	3600

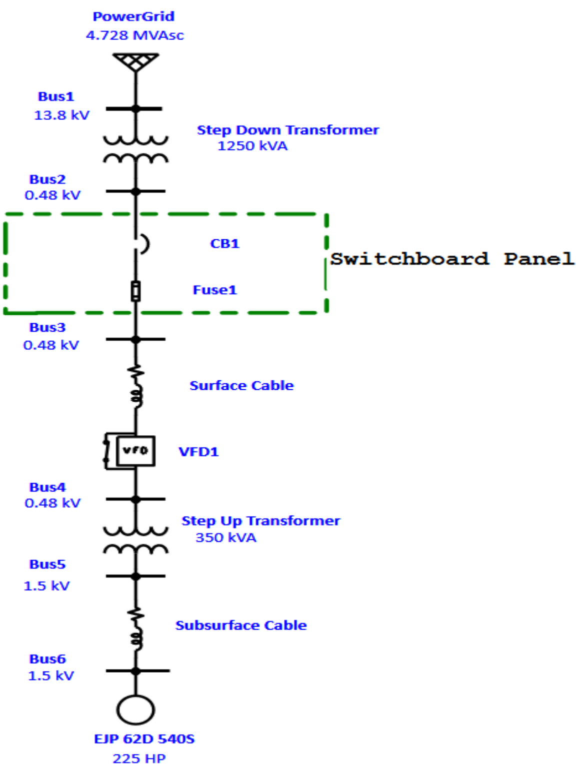

Figure 2. ESP Motor Installation Using Software

B. Determine Voltage Drop and Power Losses in Existing Conditions

In this Existing Condition, theoretical calculations will be carried out to determine voltage drops and power losses. In this case, there are several factors that cause increased voltage drop values and power losses that occur in ESP cable lines, one of which is the high temperature value in the oil well which affects the resistance of the ESP cable. Then, apart from extreme temperature factors, the cross-sectional area and length of the conductor also greatly influence the value of voltage drop and power losses, this is because the cross-sectional area of a conductor is inversely proportional to the impedance value of the cable, while the impedance value is directly proportional to value of voltage drop and power losses. The value of the voltage drops and power loss that occurs depends on the amount of electric current passed through the cable and the length of the power cable itself and the value cannot be more than 5% in accordance with IEEE standard std 141-1993. Calculations are carried out in two ways, namely simulation calculations and theoretical calculations. This was done to validate whether the theoretical calculations had shown results that were in accordance with the simulations carried out using software. Furthermore, if the evaluation of voltage drops and power losses carried out in existing conditions does not meet the standards, improvements will be made by replacing the type of cable used with a cable cross-section size that is larger than the previous size. Below, a power flow (load flow) simulation is carried out to obtain the magnitude of the voltage and power flowing to the motor terminals and the magnitude of the voltage drop and power losses that occur in the ESP cable. This simulation was carried out by referring to field parameter values measured on July 1 2023 and using AWG #2 conductor parameters.

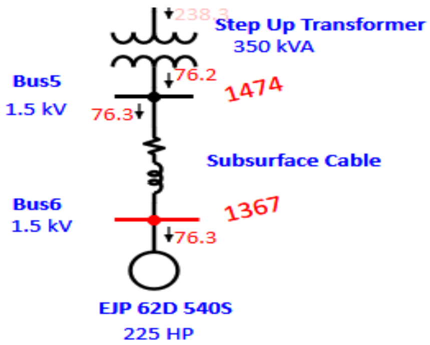

Figure 3. Power flow simulation of *existing* conditions

Figure 3 is the result of a power flow simulation carried out with reference to measurement data. This simulation was carried out referring to field data, namely using a step-up transformer with a capacity of 350 KVA and AWG#2 type ESP cable. Then the specifications for voltage are 1474 volts, current 76.3 Amperes and power 187 kW. Furthermore, the voltage drops and power losses seen in this simulation are those that occur from bus 5 to bus 6. From this figure it can be seen that the voltage drop that occurs in the ESP cable, which is indicated by the name of the subsurface cable, is 7.1% of the voltage. input and power losses that occur are 7.1% of the input power. As can be seen in Figure 4, the voltage reaching the motor terminals is only 1367 volts and the power is 175 kW, this shows that the voltage and power do not meet the operating voltage and power of the ESP motor. After carrying out a simulation using data as a sample, then to continue calculating the next measurement data, it will be carried out using Microsoft Excel, but still using the software calculation formula parameters, this is because the software cannot make changes to different current and voltage values while maintaining the same component data parameters.

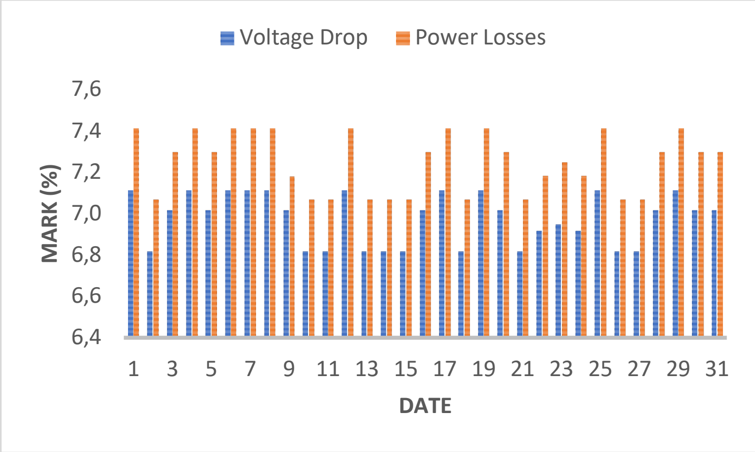

Figure 4. Simulation Calculation Graph for Existing Condition

Figure 4 is a graph of the results of calculating voltage drop values and power losses in a simulation based on data from measurements carried out for 31 days in July 2023. From the results of these calculations, there are no significant differences in values. The smallest voltage drop percentage index is 6.8% and the largest is 7.1%, while the smallest power loss percentage index is 7.1% and the largest is 7.4%. The existence of the smallest value and the largest value from the results of this calculation is because the data used is different every day. This difference is caused by the possibility that the size of the load lifted by the motor above the surface is also different every day. Next, theoretical calculations will be carried out to obtain the value of voltage drop and power losses that occur in the ESP cable, which will also be validated with simulation calculation results. This theoretical calculation will pay attention to the temperature value in the well, this is because the temperature in the oil well is very high and greatly influences the occurrence of voltage drops and power losses in the ESP cable.

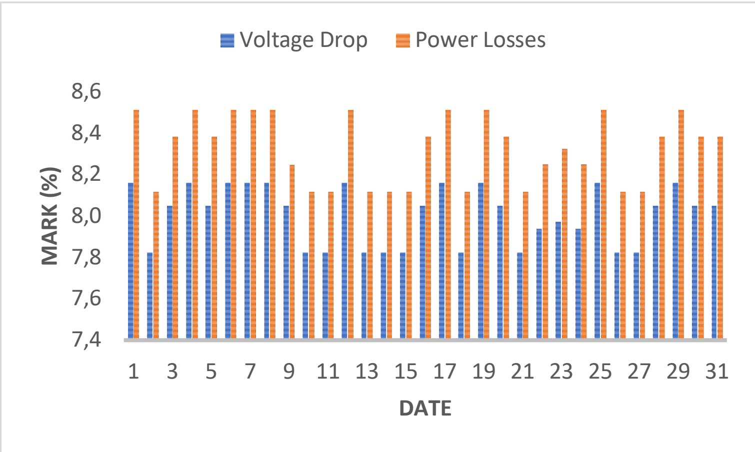

Figure 5. Calculation for Existing Condition

Figure 5 is the results of theoretical calculations of voltage drop and power losses based on data from measurements. From the results of these calculations, there are no significant differences in values. The smallest voltage drop percentage index is 7.8% and the largest is 8.2%, while the smallest power loss percentage index is 8.1% and the largest is 8.5%. The existence of the smallest value and the largest value from the results of this calculation is because the data used is different every day. This difference is caused by the possibility that the size of the load lifted by the motor above the surface is also different every day.

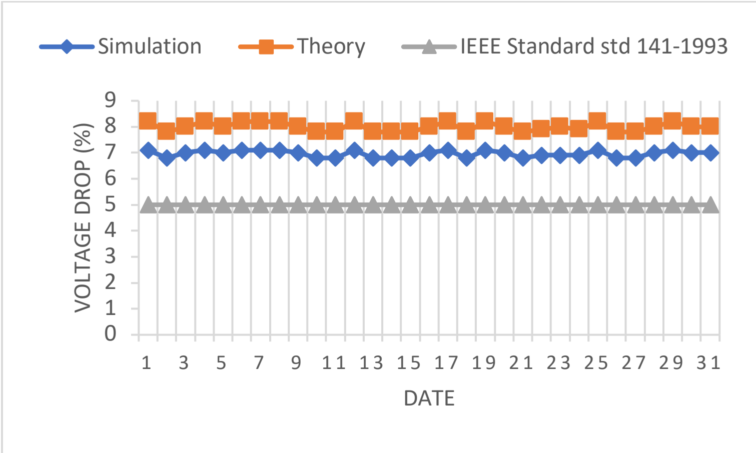

Figure 6. Voltage Drop Values Using Simulations and Theory Calculations

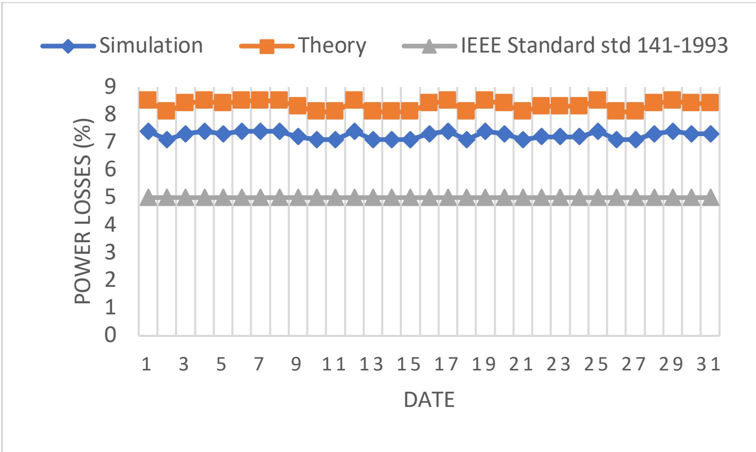

Figure 7. Power Loss Values Using Simulations and Theory Calculations

Figure 6 shows the results of calculating the voltage drop value using simulation and theoretical calculations. Meanwhile, Figure 7 shows a graph of the results of calculating power loss values using simulations and theoretical calculations. After comparing the two calculation results, there is a difference in value between the simulation calculation results and the theoretical calculation results. This difference in results occurs because the simulation calculation process does not pay attention to the temperature value in the oil well, whereas theoretical calculations must pay attention to the temperature value in the oil well which also causes the impedance value in the ESP cable to increase. Then, from the results of simulation and theoretical calculations, we obtained the results of voltage drop and power losses that did not comply with IEEE std 141-1993 standards, namely below 5%, which means that in this research It is necessary to carry out a scenario of improving the value of voltage drop and power losses that occur in ESP cables by replacing the type of cable or conductor that has a larger cross-sectional area than the type of conductor installed in the field.

C. Evaluation of Voltage Drop and Power Losses

Increasing the capacity and cross-sectional area of the wire or conductor used is one method that can be used to reduce the voltage drop and power losses. This is because the cross-sectional area and length of the conductor greatly influence the magnitude of the voltage drop and power losses. In theory, the cross-sectional area of a conductor is inversely proportional to the impedance value in the cable, while the impedance value is directly proportional to the voltage drop and power losses. Repairs to voltage drop and power losses are carried out if the calculation results for existing conditions show that the voltage drop and power losses that occur are too large and do not comply with the established standards. This repair analysis process will be carried out using several scenarios to obtain the appropriate cable cross-section size and can reduce voltage drops and power losses according to the established standards. In determining the type of conductor to be installed, including the cable on the secondary side of the transformer, namely at a voltage level of 1500 volts, you should first pay attention to the type and specifications of the ESP cable.

Table 7. Types and Specifications of ESP Cables [5]

AWG Cable	Size (mm)	Resistance at 75℃ (Ohm/1000 m)	Reactance at 60 Hz (Ohm/1000 m)	Impedance at 0,85 *PF* (Ohm)	Current (A)
4/0	14.605	0.20	0.167	0.260	260
3/0	12.954	0.26	0.171	0.311	225
2/0	11.709	0.33	0.177	0.374	210
1/0	10.337	0.39	0.180	0.429	190
1	9.169	0.52	0.187	0.552	180
2	8.229	0.66	0.187	0.685	140
3	7.518	0.82	0.194	0.842	110
4	6.553	1.02	0.197	1.03	86
5	4.620	1.29	0.205	1.306	84
6	4.114	1.61	0.210	1.623	55

Table 8 provides data on the types and specifications of Electric Submersible Pump (ESP) motor cables. These types of cables will be the parameters in this research. Currently, the ESP cable used in the field is AWG #2. Therefore, if the value of the voltage drops and power losses that occur in the ESP cable used in the field is greater than the established standards, repairs will be carried out using the first 3 scenarios. And based on Table 8, the order of cable types that will be used in the 3 repair scenarios is AWG #1, AWG #1/0 and AWG 2/0.

RESULT AND DISCUSSION

From the results of calculations carried out under existing conditions, it was found that the voltage drop and power losses that occurred in the Electric Submersible Pump (ESP) motor installation did not meet the reference standards. Therefore, an improvement scenario was carried out by changing the type of conductor used in the installation system, especially on the secondary side of the step-up transformer. In this repair scenario, voltage drop and power loss values will be analyzed using software. Then the types of conductors that will be used in this repair scenario analysis are AWG #1, AWG #1/0 and AWG #2/0 conductors sequentially to obtain voltage drop and power loss values that comply with IEEE std 141-1993 standards. From the results of calculations of voltage drop values and power losses which have been carried out both in simulation and theoretically using data, validation of these two calculation results will then be carried out. This validation is carried out to prove whether the voltage drop and power loss values obtained based on simulation calculations are in accordance with the theory that has been studied.

The results of calculating the voltage drop value carried out by simulation and theoretically in the first repair scenario. This graph shows that the percentage index for the voltage drop value in simulation is between 5.5% and 5.7%, while the percentage index for the voltage drop value in theory is between 6.3% and 6.6%. The results of the calculation of power loss values carried out by simulation and theoretically in the first repair scenario. The percentage index of power loss values in simulation is between 5.7% to 6%, while the percentage index of power loss values in theory is between 6.5% to 6.9%. The difference in the value of voltage drops and power losses between the simulation and theoretical calculations is because theoretical calculations must pay attention to the temperature value in the oil well which affects the impedance value of the cable, causing greater values of voltage drop and power losses that occur in the ESP cable. Meanwhile, in simulation, the temperature value in the oil well cannot be entered into the software. This is what causes the voltage drop and power loss values calculated in theory to be greater than those calculated in simulation. Furthermore, from the two validations, the results of the voltage drop and power losses in the first scenario are calculated by simulation and theoretically using 31 data, shows results that do not meet the IEEE std 141-1993 standard which states that the value of voltage drop and power losses in industrial plan distribution systems must be below 5%. Therefore, it is necessary to carry out a second improvement scenario.

A validation of the results of calculating the voltage drop value carried out by simulation and theoretically in the second repair scenario. This percentage index for the voltage drop value in simulation is between 4.3% and 4.4%, while the percentage index for the voltage drop value in theory is between 4.9% and 5.1%. Then, a validation graph of the results of the calculation of power loss values carried out by simulation and theoretically in the second repair scenario. That the percentage index of power loss values in simulation is between 4.4% to 4.6%, while the percentage index of power loss values in theory is between 5.1% to 5.3%. The difference in the value of voltage drops and power losses between the simulation and theoretical calculations is because theoretical calculations must pay attention to the temperature value in the oil well which affects the impedance value of the cable, causing greater values of voltage drop and power losses that occur in the ESP cable. Meanwhile, in simulation, the temperature value in the oil well cannot be entered into the software. This is what causes the voltage drop and power loss values calculated in theory to be greater than those calculated in simulation. Furthermore, the validation results of the voltage drop values and power losses calculated by simulation and theoretically in the second scenario using 31 data in July 2023, the results show that 42% of the calculations have met the standards, but 58% others do not meet the IEEE std 141-1993 standard which states that the value of voltage drop and power losses in industrial plan distribution systems must be below 5%. Therefore, to get more effective results, a third improvement scenario was carried out.

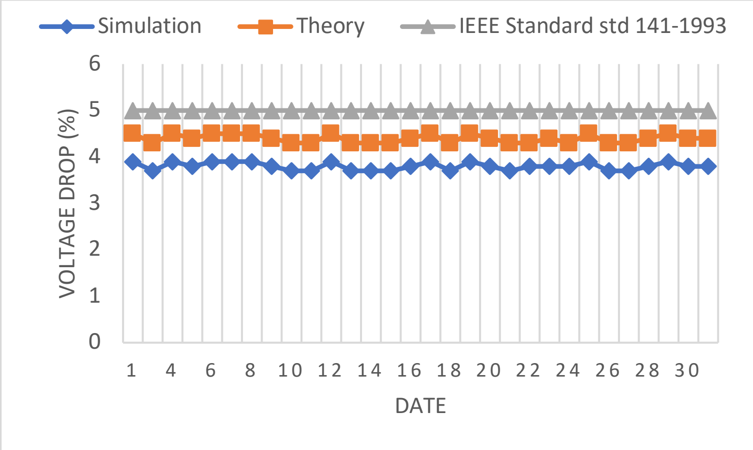

Figure 8. Validation of Voltage Drop in Scenario 3

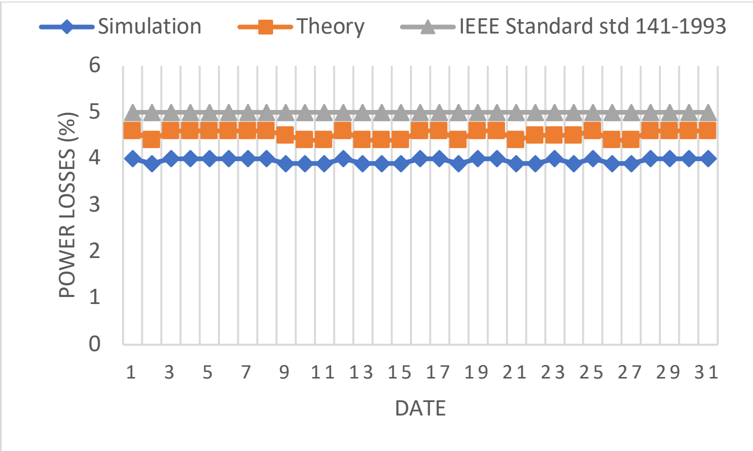

Figure 9. Validation of Power Loss in Scenario 3

Figure 8 is a validation graph of the results of calculating the voltage drop value carried out by simulation and theoretically in the third repair scenario. This graph shows that the percentage index for the voltage drop value in simulation is between 3.7% and 3.9%, while the percentage index for the voltage drop value in theory is between 4.3% and 4.5%. Then, Figure 9 is a validation graph of the results of the calculation of power loss values carried out by simulation and theoretically in the third repair scenario. This graph shows that the percentage index of power loss values in simulation is between 3.9% to 4%, while the percentage index of power loss values in theory is between 4.4% to 4.6%. The difference in the value of voltage drops and power losses between the simulation and theoretical calculations is because theoretical calculations must pay attention to the temperature value in the oil well which affects the impedance value of the cable, causing greater values of voltage drop and power losses that occur in the ESP cable. Meanwhile, in simulation, the temperature value in the oil well cannot be entered into the software. This is what causes the voltage drop and power loss values calculated in theory to be greater than those calculated in simulation. Furthermore, from the two validation graphs, the results of the voltage drop and power losses in the third scenario which were calculated by simulation and theoretically using 31 data in July 2023, show results that meet the IEEE std 141-1993 standard which states that the values Voltage drop and power losses in industrial plan distribution systems must be below 5%. Therefore, there is no need to carry out a repair scenario again. Furthermore, from the calculation results obtained in existing conditions using ESP motor installation data, these results state that the voltage drop and power losses are above 5% so they do not meet IEEE std 141-1993 standards. Therefore, an improvement scenario was carried out for the value of voltage drop and power losses. After carrying out three repair scenarios, calculation results were obtained that met IEEE std 141-1993 standards, namely in the third repair scenario with voltage drop and power loss values below 5%. Based on the calculation results of these two conditions, a comparison of the results will be carried out both in simulation and theory between the existing conditions and the conditions after repair.

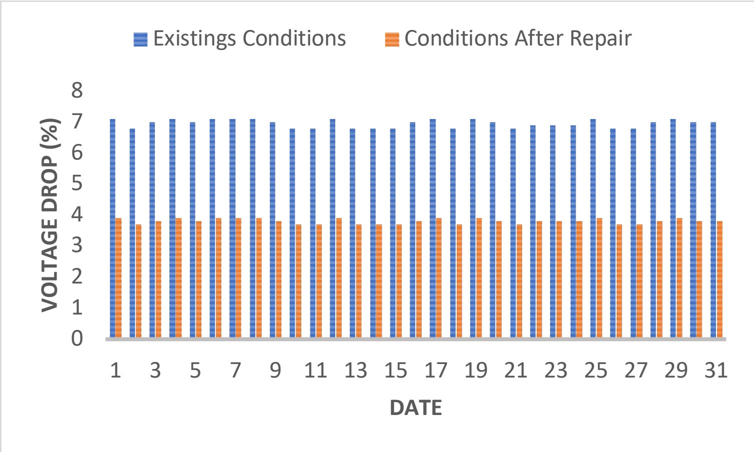

Figure 10. Comparison of Voltage Drop Values by Existing Conditions and after Repair

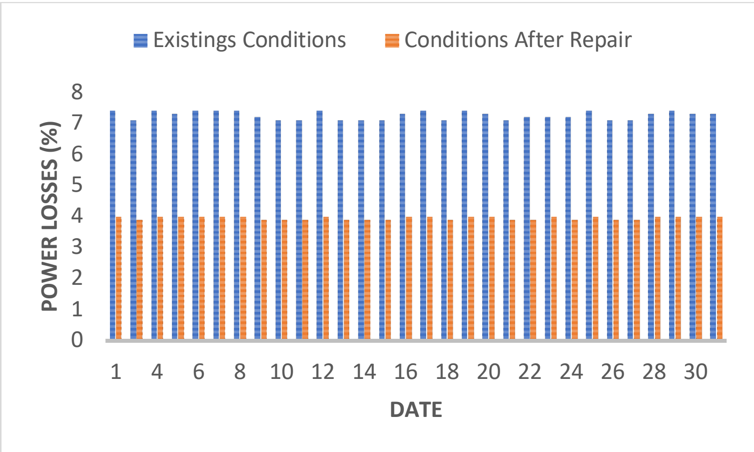

Figure 11. Comparison of Power Loss Values by Existing Conditions and after Repair

Figure 10 shows that the simulated voltage drop value in existing conditions has an average of 7.1%, while in post-repair conditions the average is 3.9%. Then, Figure 11 shows that the simulated value of power losses in existing conditions has an average of 7.4%, while in conditions after repairs the average is 4%. This shows that in the existing condition these values do not meet the standards that have been set, whereas in the condition after repair these values have met the IEEE std 141-1993 standard which states that the value of voltage drop and power losses in industrial plan distribution systems must be below 5%. The simulated voltage drop value in existing conditions has an average of 8.2%, while in post-repair conditions the average is 4.5%. Then, it shows that the simulated value of power losses in existing conditions has an average of 8.5%, while in conditions after repairs the average is 4.6%. This shows that in the existing condition these values do not meet the standards that have been set, whereas in the condition after repair these values have met the IEEE std 141-

1993 standard which states that the value of voltage drop and power losses in industrial plan distribution systems must be below 5%.

CONCLUSION

To evaluate voltage drops and power losses on ESP cables according to standards using scenario 3 by replacing the AWG #2/0 cable type with a voltage rating of 5 kV, a diameter of 11.709 mm and a current capacity of up to 210 Amperes. The voltage reduction value after repairs based on the calculation results in the simulation has an average percentage index value of 3.9% with a voltage value of 57.2 Volts, and the power losses that occur are 4.0% with a power value of 7.6 kW. Meanwhile, the voltage drop value after repairs were carried out based on the results of theoretical calculations had an average percentage index value of 4.5% with a voltage value of 65.7 Volts, and the power losses that occurred were 4.6% with a power value of 8.7 kW. The difference in the value of voltage drops and power losses that occurs between the simulation results and the theoretical calculation results is because during the simulation the temperature value in the oil well was not considered.

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