The Design of DC Motor for Robotic Hand to Install Strain Clamp Cover on Live Line Voltage 20,000 Volt

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Keywords: Motor, Mechanism, Robot.

Abstract: Economic activities that are: office activities, shops, factories/industries (small and large scale), malls, households, all of them need electricity. Electricity is the foundation sector for achieving development goals, such as creating job opportunities, increasing national income, changing the economic structure and improving people's welfare. The distribution reliability index is calculated by value of SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index). Thus, the value of SAIDI and SAIFI must be minimized the outage as small as possible. To minimize planned power outages or disturbances, robotic hands are needed to install distribution line accessories such as Strain Clamp Cover on Live Line Condition. The Analysis finding the force to close the hand robot, need 8.23 Newton was needed with a distance between the load and the hinge that are 0.262 meters. The electric motor is installed at a distance of 0.088 meters from the hinge, required DC motor with power more than 24.5 watts. After matching to the specifications of the existing motors, found a DC motor with performance 48 Watt, 12 Volt, 4 amperes. To control the DC motor, it is done with a 5 Amp capacity driver at a voltage of 12 Volts. The test results found that the maximum current is 6.6 Amperes, without any failure of operation on the motor and driver. This 48 watt DC motor supported by 5 amperes DC Controller that are available to drive the robotic hand.

1 INTRODUCTION

Economic activities that are: office activities, shops, factories/industries (small and large scale), malls, households, all of them need electricity. The growth in electrical energy as happened in China is dominated by consumer growth in the housing sector (Zhaoguang et al, 2014). Indonesia is also growing in the use of electrical energy which is quite high. Electricity is the foundation sector for achieving development goals, such as creating job opportunities, increasing national income, changing the economic structure and improving people's welfare (Santika, 2020). The distribution reliability system has a vital need to keep electricity on for 24 hours a day. Thus, the value of SAIDI and SAIFI must be minimized as small as possible.

The distribution reliability index is calculated by value of SAIDI (System Average Interupption Duration Index) and SAIFI (System Average Interupption Frequency Index) as reliability indicators. In most areas in Indonesia PLN has not been able to meet SAIDI and SAIFI standards. To minimize planned power outages or disturbances, robotic hands are needed to install distribution line accessories such as Strain Clamp Cover on Live Line Condition.

For this robotic hand driver, a driving mechanic is needed. Thus, this study discusses the driving mechanics needed for this robotic hand driver. It takes a mechanical drive with a low speed but has a hard moment. The use of a speed reducer gearbox with a speed ratio of 20:1 will result in an increase in force of 1:20 (Sobhan, 2015). For the robot hand driver, a DC electric motor will also be used which is equipped with a gearbox. The problem is how much motor power is needed and how to control the DC motor.

2 RESEARCH METHODE

2.1 Research Approach and Concept

This quantitative research approach study to find the design of a electro mechanism to drive the robotic

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hands. This electro mechanism will move the robot's hand to open and close then press the cover of the strain clamp insulator, until it closes perfectly.

The concept of this research is to convert the required mechanical compressive force at the end of the pressure point into the required electric motor power. Based on the power of the electric motor needed, research on the needs of the motor driver and microcontroller is needed.

The test of compressive force required the based load point is carried out by giving the load at the based load point gradually. The weight of the load at the based load point in the time of the robot hand closes the cover strain clamp completely, the weight of the load is recorded and multiplied by the acceleration / gravity of the earth as the required compressive force. The performance test of the DC motor and control on the robotic hand is done by observed the voltage and current changes in the DC motor every 4 seconds until the robotic hand closes completely.

2.2 Total Sample

This research was conducted with 100% sample that are 3 set of robotic hands, the collection was carried out with a total of 30 data. To obtain these 30 data, it was done by loading the water load repeatedly for 10 time for each sample until the cover strain clamp closed completely. The total of the water weight plus the container weight multiplied by the gravitational force of the earth is recorded as the force required to close the robotic hand.

Data on the test result of the performance of the DC motor and control is done by observed voltage and current in the DC motor every 4 seconds until the robotic hand closes completely. So that for one observation, 13 data were obtained for each sample because the working time was 52 seconds, the total data became 39 data for the three samples.

2.3 Variable Operational Definition

The focus of this study to observing the magnitude of the indicators of this research, that are: force, voltage, current, power and battery capacity. Voltage is amount in volt of potential test voltage between two terminal of motor DC. The current is amount in ampere of electron flow from battery to the motor DC. Power in watt or newton yang calculated to real load on the base point of load. Battery capacity was calculated to the battery insertion in to the robotic hands.

2.4 Data Analysis

Data obtained from the test results and nameplate are processed quantitatively. Data processed mathematically and statistically by finding the data variation on the step on each water filling. The data are processed mathematically to obtain the voltage, current and power at the initial of the test. The output mathematically data is processed trough statistically to obtain the average data, data sequence, which is also displayed graphically.

3 FORCE, DC MOTOR, DRIVER AND BATTERY

3.1 Force

Newton's second law of motion points out the magnitude of force when velocity of body move in force is proportional to impressed force. Mathematically, can be describe Force was change in velocity. That issue is now second law of motion is based on definition of equation of force is weigh multiple with velocity for horizontal move, and with earth gravitation for vertical move, that are as describe on this formula in below (Sarma, 2017)

$$F = M.a \tag{1}$$

The formula above can be explained that the value of the force (F) is determined by the mass value (M) of the object multiplied by the acceleration (a). The unit of force is measured in Newtons, the unit of mass of an object is measured in Kg and the unit of acceleration is measured in m/s^2(Caldwell et al., 2020)(Ariadi & Dinata, 2018).

3.2 DC Motor for Robotic

Direct Current Motor Trough electromagnetic converts the direct current electrical energy to mechanic energy(Qader, 2017). Electricity in a DC motor is flowed into the field coil so as to produce magnetic flux, electricity is also flowed through the charcoal brush to the rotor coil, so that the rotor coil produces a rotor field. The size of the mechanical power produced by the electric motor is greatly influenced by the size of the field coil and the rotor coil, so that the larger the coil, the greater the current that flows and so that the electrical power consumed is greater, resulting in large mechanical power(Iswanto et al., 2020).

To reverse the rotation of the rotor can be done by reversing the incoming current to the DC motor terminal, which was originally positive connected to a negative voltage source, and vice versa the negative one was connected to a positive voltage source(Purnata et al., 2022). This reversal of the motor terminals will result in the reverse direction of the current entering the motor, so that the motor rotation is reversed. This phenomenon occurs in accordance with the law of the left hand which reads: the index finger indicates the direction of the current, the thumb indicates the direction of the pulsation, and the other three fingers indicate the direction of the field.

3.3 Driver

There are many ways to control a DC motor. DC motors can be controlled by switches, contactors, relay, or electronic switches such as SCR and so on. The DC motor controller must have a capacity greater than the nominal current of the DC motor. Starting current affect to driving torque can overcome the load torque from the rolling resistance, the motor will already start rotating(Qader, 2017).

L298 Motor Driver is a module that is often used to control DC motors or stepper motor(Peerzada et al., 2021). By using the L298 Motor Driver easily control both the speed and direction of rotation of 2 motors at once. The L298 Motor Driver is designed using the L298 Dual H-Bridge IC. The Motor Driver contains H-Bride logic gates which are already very popular in the electronics world as controlling the speed and direction of motor rotation.

3.4 Battery

Batteries is energy storage for portable electrical equipment, as well as robotic. Batteries are the critical component for portable electric robotic live, even if they are not connected to electric energy source. Lithium-based batteries have many advantages over conventional batteries such as Nickel-Cadmium, Nickel-Metalhydrate or Lead Acid (Knowles, M.,2013). The advantages of Lithium-based batteries are high energy density, high power density, low self-discharge, fast charging, high mass-to-energy ratio, no memory effect, long lasting if the charging process is appropriate (Xiaopeng. C. et al.,2012). However, Lithium-based batteries also have the disadvantage of being less tolerant, so they require accurate monitoring and protection procedures to ensure that one of the battery cells does not overcharge, and ensure that the battery does not overheat which can reduce battery life (Ranjbar, A.H., et al.,2012).

Nowadays Lithium-ion battery that is widely used in electronic devices. The active electrode in a Lithium-ion battery is lithium metal oxide for the positive electrode while carbon is for the negative electrode. This material contains a metal collector current with a binder, usually polyvinylidene fluoride (PVDF) or polyvinylidene fluoride-hexafluoropropylene (PVDF-HFP) copolymer, and a conductive diluent.

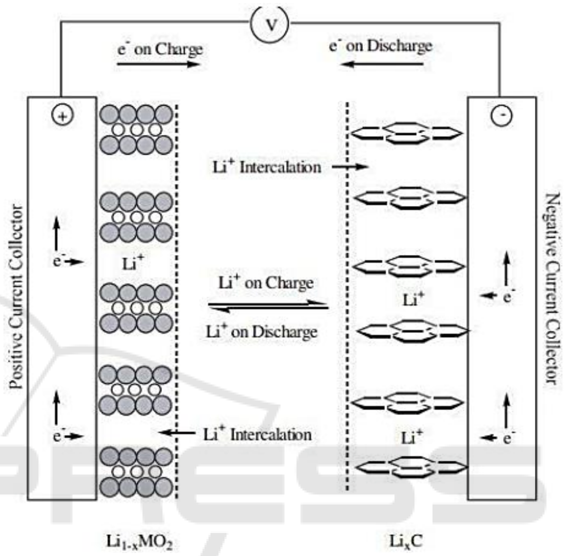

Figure 1: Electrochemical process in lithium-ion batteries.

The capacity of a battery is greatly influenced by the quality of the material and the dimensions of the material, so that in the same type it will appear that the dimensions are larger for a larger battery capacity. The capacity of the battery at a certain voltage will be described by how much current can be stored by the battery in ampere hours (ampere hours).

4 DC MOTOR AND CONTROL DESIGN

4.1 DC Motor Design

The amount of DC motor power required to carry out the robotic hand functions is influenced by the force as the load of DC motor. The magnitude of the force load of the DC motor (Newton) in the robotic hand is influenced by three values, including: (1) the value of the distance (meters) of the DC motor to the fulcrum, (2) the value of the distance (meters) from the fulcrum to the load point, and (3) the compressive force (Newton) required by the load.

The required of compressive force of the robotic hand to close the strain clamp cover is carried out by tested using a dummy load by a water container. The water container is placed at the end point of load from the fulcrum. Water is poured into the container slowly until the robotic hand closes to closes the strain clamp cover. When the strain clamp cover is completely closed, the water pouring is stopped.

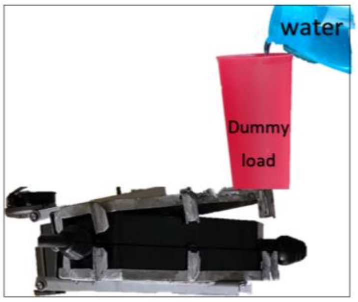

Figure 2: Loading test.

The water and the container are taken from the robotic hand to measured its weight. The weight of the water and the container is multiplied by the earth's gravity of 9.8 m/s2, then the value of the compressive force required to closed the strain clamp cover perfectly. The test results of three samples of robotic hands, each sample was loaded 10 times, so that the total data is 30 data were obtained. The data is processed statistically, so the graph and the average compressive force will be obtained. The test result data can be shown in the table below.

Table 1: Force test result.

NO	Sample 1		Sample 2		Sample 1	
	Weight (Kg)	Force (N)	Weight (Kg)	Force (N)	Weight (Kg)	Force (N)
1	0.9	8.82	0.85	8.33	0.84	8.23
2	0.89	8.72	0.84	8.23	0.88	8.62
3	0.85	8.33	0.84	8.23	0.87	8.53
4	0.82	8.04	0.83	8.13	0.85	8.33
5	0.8	7.84	0.85	8.33	0.82	8.04
6	0.85	8.33	0.84	8.23	0.8	7.84
7	0.84	8.23	0.83	8.13	0.83	8.13
8	0.83	8.13	0.83	8.13	0.84	8.23
9	0.83	8.13	0.82	8.04	0.83	8.13
10	0.82	8.04	0.85	8.33	0.83	8.13
Average Weight (Kg)			0.84	Average Force (Newton)		8.23

Based on the data at table 1, the data variation can be describe by the chart at the figure 2 below. The variation of the quality strain clamp cover affect to the variation of weight of dummy load to get the perfect closes.

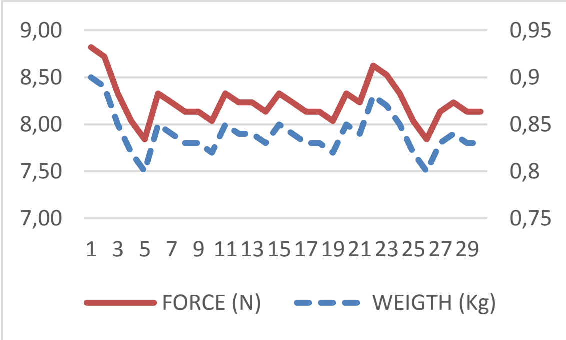

Figure 3: Variation of loaded.

The placement of the DC motor and the load point, carry out the load distributed can be explained in the figure 3 below.

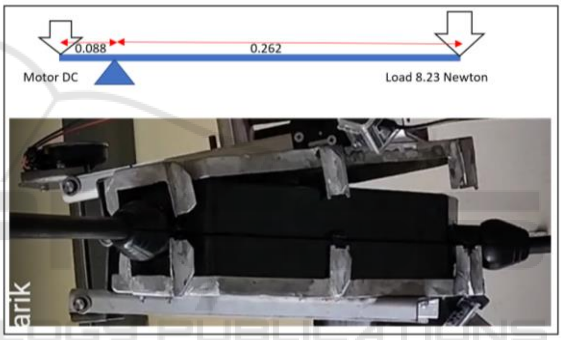

Figure 4: Robotic hand load distribution.

Like in the figure 3 can be describe (1) the value of the distance of the DC motor to the fulcrum is 0.088 meters, (2) the value of the distance from the fulcrum to the load point is 0.262 meters, and (3) the required of compressive force is 8.23 Newton. Based on this data, the DC motor power can be analysis trough balance load principles, as describe at below.

$$F_1 x l_1 = F_2 \text{ x } l_2$$

$$F_1 \text{ x}0.008 = 8.23 \text{ x } 0.262$$

$$F_1 \quad = 8.23 \text{ x } 0.262 / 0.008$$

$$F_1 \quad = 24.5 \text{ Newton}$$

Base on the calculation, to drive the robotic hand the DC motor must be produce force more than 24.5 Newton, that are similar more than 24.5 watt, the assumption is no friction loses.

Based on the calculations above, for the robotic hand driver, a motor above 24.5 watts is needed. Found on the market a complete DC motor gearbox, with a capacity of 48 watts, 12 volts, 4 amperes as shown in the picture below.

Figure 5: DC motor 48 watts.

Based on the data shown in table 3 and graphs in the figure 5, it appears that the DC motor electric current shows an increasing trend in the process of closing the robotic hand. The graph shows the electric current soaring up at the end, because there is a process of locking the strain clamp cover. The graph also shows that the stress drops during the strain clamp cover locking process.

4.2 Control Design

Based on the choice of the DC motor used to drive the robotic hand, to determine the driver design, the maximum DC motor current is calculated. The data on the DC motor nameplate shows 12 volts of 48 watts (0.064 hp). The calculation of the maximum motor current is calculated as below.

I = P/V

I = 48/12 = 4 Amperes

Taking the calculation results of the above, that the nominal DC motor current is 4 amperes, the driver to control it must have a capacity higher than 4 amperes. Searches in the market show 4 amperes drivers which are easily available are drivers with a 5 amperes capacity, as shown in the image below.

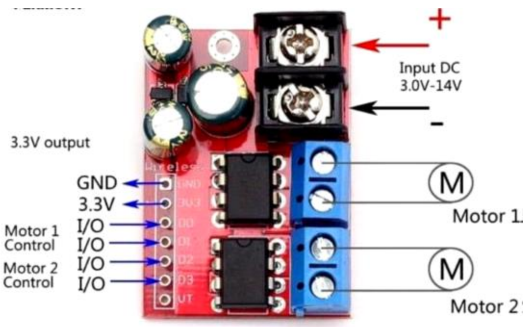

Figure 6: DC motor controller l298.

5 RESULT AND DISCUSSION

The results of the research are shown in numbers arranged in a table. The data from the test results are discussed by mathematically and statistically analysed, which is finally displayed in the form of a graph.

5.1 Result

To drive the robotic hand, the gearbox motor is coupled with a trapezoidal thread to propel the arm. The performance tested of the DC motor in the robotic hand, to determine the electric power consumption.

Table 2: Voltage and current test result.

NO	Sample 1		Sample 2		Sample 1	
	Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)
1	5,3	1,34	5,4	1,35	5,2	1,38
2	9,6	1,34	9,6	1,35	9,7	1,34
3	9,7	1,7	9,8	1,7	9,8	1,7
4	9,6	1	9,7	1,2	9,6	1,23
5	9,8	1,68	9,8	1,68	9,9	1,66
6	9,6	1,9	9,6	1,9	9,6	1,9
7	9,7	1,66	9,8	1,68	9,8	1,68
8	9,5	1,7	9,5	1,7	9,6	1,65
9	9,6	1,8	9,6	1,8	9,7	1,78
10	9,5	1,79	9,4	1,81	9,5	1,78
11	9,1	2,1	9	2,3	9,2	2,26
12	9,5	2,15	9,4	2,17	9,6	2,14
13	6,5	2,69	6,7	2,66	6,6	2,68

5.2 Discussion

Observing the data in table 2, it is necessary to do statistical processing, to find the average voltage and current. The DC motor terminal voltage up and down according to the magnitude of the load current at every moment of the robotic hand closing process. Each change in the voltage value of the three samples is added up and then divided by three, then the average voltage is obtained so do that for current flowed to the DC Motors. The results of this processing will contain 13 voltage data and 13 current data, respectively. The data explained the performance of DC motor to drive the robotic hands. Through statistical processing, can be obtained the data contained in table 3.

Table 3: Current and voltage analysed.

NO	Average	
	Voltage (V)	Current (A)
1	5,30	1,36
2	9,63	1,34
3	9,77	1,70
4	9,63	1,14
5	9,83	1,67
6	9,60	1,90
7	9,77	1,67
8	9,53	1,68
9	9,63	1,79
10	9,47	1,79
11	9,10	2,22
12	9,50	2,15
13	6,60	2,68

Based on the data at table 3, the data variation can be describe by the chart at the figure 5 below. The variation of the current affect to the voltage of battery for every step of closing process.

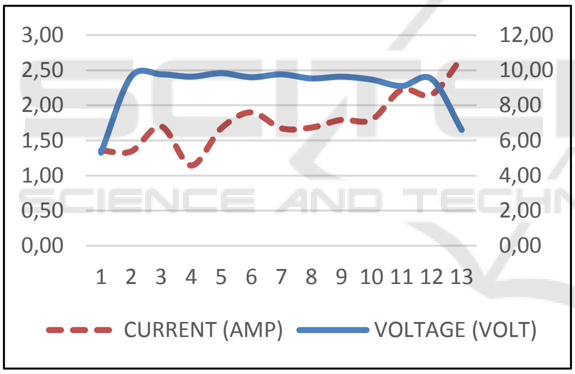

Figure 7: Current trend.

The drivers l298 was installed to control DC Motor, with a 5 amperes capacity, rated voltage 3 Volt up to 12 Volt. The choice of the l298 driver is the right and safe choice. With a nominal current capacity of 5 amperes, this driver will easily control a DC motor that works with an average maximum current of 2.8 Amperes.

To support the performance of this robotic hand, 3 pieces 4.5 Volt 3ah batteries are used, connected in series. This battery was chosen because the DC motor current is close to 3 amperes. With this battery, the robotic hand will be able to operate for 45 minute non-stop. This battery is also equipped with a battery management system, with a nominal current capability of 30 Amperes as shown in the image below. Battery must be

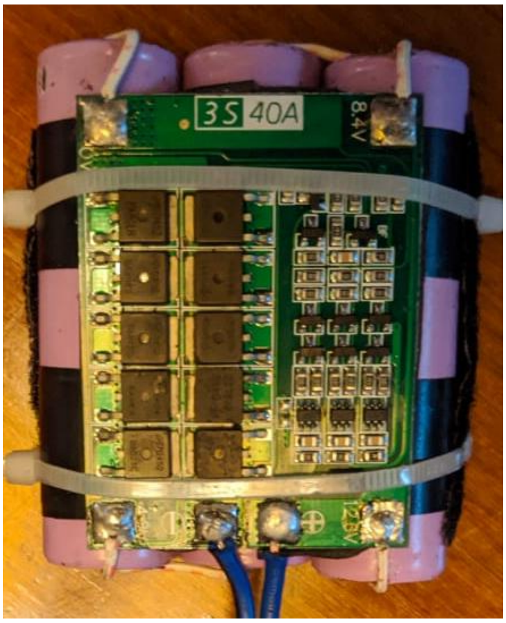

Figure 8: Battery.

6 CONCLUSIONS

Based on the results of testing and analysis can be concluded as follows:

1. To drive for robotic hand with 8.23 Newton workload, are sufficient a DC motor 48 watts 12 volt.
2. Drivers at a capacity of 5 Amperes are sufficient to controlled DC motor for a robotic hand with a maximum working current of 2.98 Amperes.
3. The battery 12 volt, with a capacity of 3 ah, is enough to supply 75% of its capacity to a DC motor with a maximum operating time of 45 minutes non-stop.

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