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APPLICATION OF ELECTRO-MECHANICAL ACTUATOR FOR SWITCHGEAR MECHANISM TESTING

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Abstract— **Switchgear products undergo various type testing before moving to mass production. These testing can be divided in destructive & non-destructive testing. Endurance test which is kind of destructive test specifies product life. Endurance tests are conducted with or without electrical load named respectively "Electrical endurance test & Mechanical endurance test. Life of products depends on various factors & it can vary from few operations to millions of operations. To perform such life test pneumatic systems are most popular among type test houses due to its low operating cost. Still it does have drawbacks like, high installation cost, high maintenance cost, immobility, complex pneumatic system, low reliability, low accuracy, stroke length, speed & force restriction etc. Idea behind the project was to develop a system to resolve the drawbacks with keeping the merits of pneumatic system. The project is development of cost effective, reliable & fully automated system to conduct endurance test with high accuracy & relevant data capturing through cloud computing. This system includes an electromechanical actuator, measurement devices like load cells to measure force, torque etc., and a digital controller to compute & automate all the process involved towards achieving a detailed endurance test results.**

Keywords--- **Electromechanical, actuator, Endurance switchgear**

I. INTRODUCTION

The Electrical & Automation Independent Company (EAIC) of L&T is one of the divisions involved in the design, manufacture and marketing of a comprehensive range of low voltage switchgear and other electrical and electronic products in areas of automation, energy management and medical equipment.

L&T is India's largest manufacturer of low voltage switchgear & control gear as well as petrol metering & dispensing pumps which functions as The Electrical Group, earlier known as Group III,handles these functions, an independent profit centre within the corporate ambit of L & T. The group manufacturing facilities are located at Powai, Ahmednagar and Faridabad.

The Switchgear Testing Laboratory in their Powai campus has the following four stations-

1. Short Circuit Lab
2. Electrical Endurance Test Section
3. Thermal Lab
4. Mechanical Endurance Testing Lab

The Mechanical Endurance Testing Lab is the place where the concerned project is being carried. There are various sections in this lab viz.

i) Mechanical Endurance
ii) Environmental laboratory
iii) Switchgear Design and Development Centre (SDDC)
iv) Calibration Centre
v) EMC HV Section

The sole purpose of the project is to make a suitable and **economical** machine to test the Number of Times a MCCB can turn ON and OFF i.e. the life of the MCCB. The system should have the similar operations but have the running cost minimum and as low as possible. The coming chapters will explain in detail the process of selection and design of a system for the Life Testing machine.

II. THE PNEUMATIC SYSTEM

The current system under working which is used for testing the Life and the Mechanical Endurance of the MCCB's is a Pneumatic actuator system governed by PLC.
The below given picture of the system explains the operation-

Current Pneumatic System
Fig.1

III. PROBLEM DEFINITION

The current system of testing the life of the switchgears incorporates pneumatic principle driven actuator which has a reciprocating to & fro motion of piston inside a cylinder which helps to turn ON and OFF the switches. The problem or limitation of the current system is that it is too much expensive and noisy in operation. The cost of the setup is given below-

1. Compressor (Qty: 01)
• Initial Cost – 6Lac
• Maintenance – 1.5 Lac yearly
• Life-3-4 Years

2. PLC/Time controller (Qty: 01)
• Initial cost – 10000 x10- 1Lac
• Maintenance - Nil

3. Cylinder Controller (10 Nos.)
• Cost – 3000x10=30000
• Maintenance – 10000

4. Cylinders
• 5000x10=50000 (1 Year - Life)
5. Pneumatic Pipes

ADVANTAGES:
1. The air used is free of cost and easily available.
2. The motion obtained is accurate.
3. Life of the components is good enough.
4. Once operation is started no necessary to inspect because of PLC control.

DISADVANTAGES:
1. The cost of the system is very high.
2. The maintenance schedules need to be done frequently.
3. The setup time is large enough.

IV. STUDY OF ALTERNATIVES

The disadvantages of the pneumatic system rolled the wheel to think about the possible alternative solutions for obtaining the same motion with same or even greater accuracy and eliminating all the limitations of pneumatic system with greater control and lesser need of the human attention.
The below given are the possible alternatives that studied and suggested for replacement of the existing system.

ALTERNATIVE 1. SERVO SYSTEMS

Based upon the working principle and the motion of the required systems the Servo systems is the best candidate with the following economic point of view-
Investment

1. Servo Motor + Drive
- Initial Cost – 1.5x10=15 Lac
- Maintenance – Minimal

2. Servo Controller
- Initial Cost -1 Lac
- Maintenance – Minimal

3. PLC / Timer
- Initial cost – 10000x10=1 Lac
- Maintenance - Minimal

4. Coupling shaft
- Initial Cost – 25000
- Maintenance – Minimal

ADVANTAGES:
1. Smooth power and reliable operation
2. Efficient control over the system parameters

DISADVANTAGES:
1. Very Costly both in fixed and running costs
2. Initial cost of the setup is also very high
3. Maintenance needs to be done frequently
4. Skilled operators are required

CONCLUSION: Thus the Servo Systems do provide a good alternative but they are very costly which eliminates the very requirement of the project to be economical.

ALTERNATIVE 2. REVERSIBLE AC SYNCHRONOUS SYSTEM

The Reversible AC Synchronous System incorporating the AC Induction Motor was considered here as the second alternative for obtaining the similar motion as that required.
The following costs were associated with this system-
Investment

1. AC reversible Synchronous Motor
- Initial Cost – 5000x10=50000
- Maintenance – Minimal

2. Drive - Not required

3. Controller
- PLC/Timer

Cost 10000*10 -1 Lac

4. Coupling shaft
- Initial Cost – 1 Lac
- Maintenance – None

5. Gear System

ADVANTAGES:
1. The suitability of the AC motor to the working environment is high
2. The operation is simple and easily controlled using a PLC.
3. The range of cost is within acceptable limits.

AC motor System
Fig.2

DISADVANTAGES:
1. The AC motors suffers from the ill effects of the inertia loading.
2. The losses in the current due to hysteresis is significant
3. The maintenance of the system needs to be done frequently.

CONCLUSION: Thus the Reversible AC Synchronous System has cost compatibility but does not satisfy the accurate motion control needs. Hence it cannot be used for the new system.

ALTERNATIVE 3. ELECTRO-MECHANICAL ACTUATOR

The ELECTRO-MECHANICAL ACTUATOR System incorporating the Electromagnet was considered here as the third alternative for obtaining the similar motion as that required.
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Components of an Electro-Mechanical Actuator
Fig.3

The parts required for trying this actuator are

Sr. No.	Part Name	Material	Quantity
6	Stator (Outer Cylinder)	M.S.	2
5	Bobbin	Plastic	2
4	Solenoid(wire)	Copper	2
3	Inner Stator	M.S.	2
2	Joiner	Aluminum	1
1	Actuator (Plunger)	M.S.	1

Analytical Design

To calculate the force in a solenoid design with a steel slug the following equation can be used:

$$F = \mu \frac{dB}{dX}$$

The magnetic field can be calculated by:

$$B = \frac{\mu_o NIR^2}{2}\left\{\frac{1}{R^2+x^2\,{}^{\frac{3}{2}}} + \frac{1}{R^2+x^2-2sx+s^2\,{}^{\frac{3}{2}}}\right\}$$

The change in the magnetic field can be calculated by:

$$\frac{dB(x)}{dX} = \frac{\mu_o NIR^2}{2}\left\{\frac{3x}{R^2+x^2\,{}^{\frac{5}{2}}} + \frac{3(x-s)}{R^2+x^2-2sx+s^2\,{}^{\frac{5}{2}}}\right\}$$

Where;
μ0 = permeability of free space, 4*pi *10^-7 H/m

μ0 = permeability =875*10 ^-6H/m

N=number of turns

I= current 1.2 A

L=length= 0.115* 2= 0.230 m

X= position from the centre of the left coil

S=position of centre of right coil

r = radius = 0.035 m

B=magnetic field strength

Theoretical Calculations –

The calculations below determine the current density in the coil for the purposes of simulation.

Coil window area:

A=114*18 = 2052 mm

Wire size:

$A=3.14*(0.25^2) = 0.1963mm^2$

Theoretical turns in coil window:

T= 2052/0.1963 = 10453

Air space per winding

$Aa = (2r^2 *1.7320/2)*3.14*r^2 =0.0202mm^2$

Therefore area taken by each winding:

At = 0.1963+0.0202 =0.2165mm^2

Calculated turns:

Tc = 2052/0.2165 =9478

Current carrying capacity of 0.2mm^2 copper wire:

Iccp = 1.2A

Therefore current density:

Id=9478*1.2 = 11374 At

Solenoid Force Calculator				
I (Current In Amps.)	1.2		(A)	
N	9478		(turns)	
A	22.6		(Length units^2)	
g	3		(Length units)	
Results				
Compute				
F	204.099	(N)	45.883	(LBS)

Result 1

This calculator computes the force between a solenoid and another piece of ferromagnetic material separated by a gap of distance g.

$$F = (Fm)^2 \mu_0 A / (2 g^2)$$

$$F = (N*I)^2 \mu_0 A / (2 g2),$$

Where;

- $\mu_0 = 4\pi\times10\text{-}7$
- F is the force in Newtons
- N is the number of turns
- I is the current in Amps
- A is the area in length units squared
- g is the length of the gap between the solenoid and a piece of metal.

Note, any units can be used for A and g so long as they are consistent.

Estimated Cost

So basically out of this 6 parts which have mentioned earlier need to fabricate the 4 parts except for the wire and Bobbin (plastic -material)

1. Cost of fabrication
   - Initial Cost – upto 6,000
   - Maintenance – Minimal

2. Drive - Not required

3. Controller
   - PLC/Timer

   Cost 10000*10 -1 Lac

4. Latching Circuit
   - Initial Cost – Rs.500
   - Maintenance – None

V. SELECTION OF OPTIMUM ALTERNATIVE SYSTEM

Out of the 3 alternatives which are mentioned above, one of them is finalised for project. The finalising of the alternative has been done considering various factors and why the chosen alternative will be beneficial for project. Considering the different merits the alternative will give Vs the demerits that can be occurred have been taken into account. With the help of all the mentioned factors have come to the conclusion that will choose ELECTRO-MECHANICAL ACTUATOR as actuating system.

The reason for choosing this actuating system is because when taken into account the advantages as well as disadvantages of all the three alternatives the advantages of this electromechanical actuator are greater than the other two.

When it is needed to finalise any of the alternatives the advantages or the merits of the particular system should be considered but it also must take into account the demerits or the disadvantages that can occur. The point here is that if for a particular system there are 10 advantages but unfortunately there are also 8 disadvantages then there is no point is choosing that alternative. Whereas on a same note where there are just 6-7 advantages of a particular system and only 1-2 disadvantages then there is no problem is choosing that alternative.

The reason going for the in-house production is that first thought of the readymade solenoid actuators which one can get easily in the market.

But the problem faced here was the travel length which is require for this application is not been satisfied by any solenoid making company.

- The maximum displacement which is possible in readymade solenoids from market is only **upto 50-60mm**
- But the required displacement of system is about **100mm**
- This is the reason to design the system in-house itself
- Principle used in the proposed system is same as that of applied in the solenoid actuators.

Possible Losses/Drawbacks in **ELECTRO-MECHANICAL ACTUATOR**

In any system Drawbacks are bound to come and yes there are ways to eliminate them but some of the drawbacks are such that they cannot be even eliminated as they are not in our hands and there is no way one can control them. It is actually there natural tendency to work in that way hence cannot be controlled.

There are chances that the below mentioned drawbacks can occur in system.

- System works on principle of electromagnetism and the power required for actuation may not be as per theoretical calculations
- Setup is vertically oriented and 50% of the time the plunger has to be floating in air without any support at base
- The only support the plunger will get is from the attraction force created by the electromagnet.

Why this setup will be beneficial than the current setup

- The major point to be considered is the cost optimization factor
- The current setup requires compressor as it is based on the principle of pneumatics but in the proposed system no need of any compressor hence cost will be saved
- As there is no compressor so no cost in maintenance
- Cost of pipes which is currently required will not be required.
- The network system of cables and hoses from a single compressor to various units is eliminated
- Annual savings of 1.5 lac due to absence of compressor
- The reliability of the electrical oriented system is always high.
- Life is considerably longer since it has to work on 50% duty cycle

VI. CONCLUSION

The study of different types of systems shows that the Electromechanical Actuator seems to be very promising for the required task. Though there are some limitations for the selected system but its advantages over the existing one is very expressive.It will reduce the operating and setup cost upto 60%. The compactness, ruggedness and the economy of the design gives it an upper hand edge towards its implementation in the testing of the switchgears. The design and the modelling phase have been completed and the only work which has remained on hand is to manufacture it and test its effectiveness while it is in operation while working along the true conditions. Though being from Mechanical Domain, level best has been tried to assimilate the basic and general principles of design of systems in Electrical Engineering with the design and approach of Mechanical Engineering. The efficiency of the design is yet to be known through actual evaluation in test environments.

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VIII. REFERENCES

[1] Ferromagnetism. (2009, April 30). http://en.wikipedia.org/wiki/Ferromagnetic

[2] Georgia State University. (2005). Electromagnet. http://hyperphysics.phyastr.gsu.edu/hbase/magnetic/elemag.html#c4

[3] A. K. Sawhney, "Electrical Machine Design" Dhanpat Rai & Sons Publications

[4] Wikipedia. (2009, April 30). Magnetism. http://en.wikipedia.org/wiki/Magnetism

[5] Neodymium magnet (2009, September 30). http://en.wikipedia.org/wiki/Neodymium_magnet

[6] S. Pithadia, "Driving solenoid coils efficiently in switchgear applications" Texas Instruments Application report SLVA460-March-2011-Solenoid Driving With DRV8841/42

[7] www.saia-burgess-usa.com/ledex-Tecnical-data,for solenoids

[8] Diamagnetism. (2009, April 27). Retrieved May 4, 2009, from Wikipedia: http://en.wikipedia.org/wiki/Diamagnetic

[9] STANDARD AND CUSTOM SOLENOIDS FOR OEM APPLICATIONS, www.pennyandgiles.com

[10] http://galileoandeinstein.physics.virginia.edu/more_stuff/E&M_Hist.html

[11] J. Grimm, "*Electromagnetic linear actuator - design, manufacture and control".* B. Tech Project Thesis, University of Southern Queensland, Australia, 2009

[12] National Semiconductor. (2005, April). LMD18200.pdf. Retrieved August 15, 2009, from National Semiconductor: http://www.national.com/ds/LM/LMD18200.pdf

[13] Cabrillo College. (n.d.). Chapter 29: Magnetic Fields due to Currents.Retrieved October 5, 2009, from Cabrillo College