Pertanika J. Sci. & Technol. 25 (S): 61 - 68 (2017)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Field Evaluation of Magnetic Actuator Driven Switchgear in Malaysia

Mohd Dzaki, Mohd Amir* and Sanuri, Ishak

Distribution Unit, TNB Research Sdn Bhd, Kajang, Malaysia

ABSTRACT

Magnetic actuator driven switchgear is a new medium voltage switchgear technology. In this switchgear, the conventional spring mechanism which is used to operate the circuit breaker is replaced with a magnetic actuator mechanism. The suitability of this technology in the Malaysian utility network specifically in highly loaded areas with frequent switching was assessed via a field evaluation. Preliminary results indicated that magnetic actuator driven switchgear perform commendably on the safety aspect, on-site performance monitoring and online diagnostic test results. However, there are several concerns that need to be addressed such as the ease of installation, substation system requirements, high life cycle cost and reliability of components, before this technology can be used widely.

Keywords: Magnetic actuator, medium voltage switchgear, condition monitoring, life cycle

INTRODUCTION

All the medium voltage switchgears in Malaysia achieve tripping and closing operations of the circuit breaker with the conventional mechanical spring and latch mechanism. However, several models of switchgear which use the spring mechanism suffer from the so-called sluggishness issue, in which the circuit breaker failed to trip within the allocated time. This is caused by the hardening of lubrication (i.e. grease) as the circuit breaker can remain idle for long periods. The impact of which can cause a large number of consumers being affected when there is a breakdown (Muttalib & Amir, 2010).

One way to resolve this issue is to replace the conventional spring mechanism with switchgears that use magnetic actuator as the primary operating mechanism. Magnetic actuators use changes in the direction and force of magnetic fields to move or control

ARTICLE INFO

Article history:
Received: 24 August 2016
Accepted: 03 Jun 2017

E-mail addresses:
dzaki.amir@tnbr.edu.my (Mohd Dzaki, Mohd Amir),
sanuri.ishak@tnbr.com.my (Sanuri, Ishaki)
*Corresponding Author

ISSN: 0128-7680

a mechanical system (Jiles, 1998). Figure 1 shows a typical implementation of the magnetic actuator mechanism in medium voltage switchgears. In switchgears, electromagnets and permanent magnets are used together to provide the operating energy for the movement of the circuit breaker contacts as well as the essential bi-stable characteristic for both close and open conditions. A single moving part can replace the hundreds moving parts contained in a conventional switchgear spring mechanism (Lane, 1998). Therefore, the magnetic actuator mechanism has the advantages of increasing reliability by reducing mechanical parts count, smaller size and no longer need to maintain the mechanical parts compared to the conventional spring mechanism.

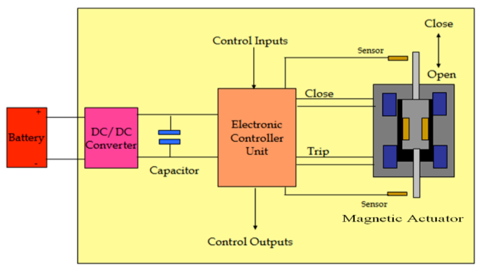

Figure 1. The magnetic actuator components which is used to operate the circuit breaker. This mechanism replaces the conventional spring mechanism

M Amir et al. (2013) performed a study to assess crucial areas for the reliable operation of the switchgears not covered in switchgear type tests. The study evaluated the major components of the magnetic actuator mechanism which are the magnetic actuator itself, electronic controller unit and capacitor, the performance of the switchgear panel as a whole as well as comparative analysis with the conventional spring mechanism via laboratory tests and finite element simulation.

M Amir et al. (2013) concluded that based on the laboratory test and simulation results, the magnetic actuator mechanism can be a viable alternative to spring mechanism. However, a field trial in an actual substation is required to study the performance in actual utility application.

The objective of this study is to determine the suitability and practicality of using magnetic actuator driven switchgear.

METHODOLOGY

In this field evaluation, five panels of magnetic actuator driven switchgear were installed in an actual substation. The configuration of the panels is as follows:

- 2 incomer panels
- 2 outgoing panels
- 1 bus-section panel

Figure 2 shows the single line diagram of the installed switchgears while Figure 3 is a photo of the actual installation on-site. The following activities were performed during the field evaluation:

- Site selection
- On-site performance monitoring
- Technical and financial assessment

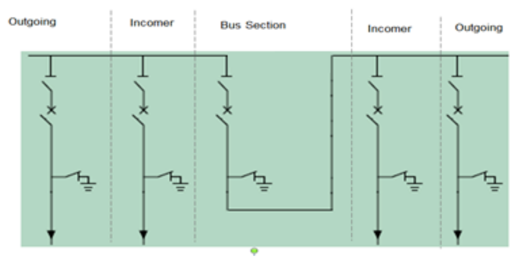

Figure 2. Single line diagram of the installed switchgears consisting of two incomer panels, two outgoing panels and one bus-section panel

Figure 3. Installation of the magnetic actuator driven switchgear in the trial site

Site selection

Correct site selection is necessary in order to arrive at an accurate representation of the long-term switchgear performance during field evaluation. The following criteria were used in determining the most suitable site for this field evaluation:

- Frequent switching operation: to assess the capability and reliability of the magnetic actuator during switching operations.
- High current loading: to test the switchgear up to its full current rating.
- Highly polluted: to determine the effect of environment to the switchgear.
- Network: the substation must have proper back up plan any failure happens during this field evaluation

- Connectivity: The substation must be connected to the regional control centre in order to allow online switchgear control and performance monitoring

A substation in an urban industrial area in the State of Selangor was selected as the location for this field evaluation as it met all the criteria listed above.

On-site performance monitoring

This activity was performed to assess the performance of the magnetic actuator driven switchgear during the six-month field evaluation period. The monitoring consists of two major parts which are:

1. **Online diagnostic tests.** There are three online diagnostic tests which are performed during the field evaluation period. These are thermography inspection and ultrasonic scanning. Thermography inspection was performed to determine the existence the hot spots especially in the contact parts of the switchgear. Ultrasonic scanning was performed to determine the insulation condition specifically the existence of partial discharge. All these tests were performed monthly during the field evaluation.
   In addition, a partial discharge monitor was installed during the first and sixth month of the field evaluation. This equipment monitors the switchgear to determine the presence of partial discharge. The partial discharge detection method is by measuring the transient earth voltage (TEV). Trending analysis was then performed on the data obtained from the diagnostic tests to determine any signs of deterioration of the condition of the switchgear.
2. **Switchgear performance assessment.** Apart from the diagnostic tests, the performance of the switchgear when switching operation was performed was also collected. The sources of the data were data from the regional control centre as well as feedback from the operators.

Technical and financial assessment

This was performed to determine the suitability of using the magnetic actuator driven switchgear via two major aspects:

1. **Technical assessment.** The areas studied in technical evaluation include compliance to existing technical specifications and standard practice, ease of installation, ease of operation and maintenance, component reliability and safety aspect.
2. **Financial assessment.** For this purpose, the total life cycle cost of the magnetic actuator driven switchgear was calculated and compared to the life cycle cost of the existing air insulated switchgear with conventional spring mechanism. The life cycle cost consists of the purchase cost, installation cost, operation cost, condition monitoring cost, periodic maintenance cost, breakdown maintenance cost, spare parts cost and disposal cost (Loo, Y. H., et al. 2010).

RESULTS AND DISCUSSIONS

Online diagnostic tests

Table 1 below shows the limits used to interpret the results of the online diagnostic tests. The limits are based on the standard condition based maintenance interpretation guidelines used by TNB Distribution Division (TNB, 2013).

Table 1
Interpretation of the online diagnostic tests

Diagnostic test	Measurement	Results	Condition
Thermography	Temperature difference with ambient temperature Ultrasonic reading TEV magnitude	1 – 4°C	Normal
		5 – 9°C	Intermediate
		10 -14°C	Serious
		> 15°C	Critical
Ultrasound		0dB	Normal
		> 1dB	Serious / Critical
TEV		< 15dB	Normal
		16 – 25dB	Intermediate
		26 – 35dB	Serious
		> 35dB	Critical

The online diagnostic test results obtained during the field evaluation are in Table 2 below:

Table 2
Online diagnostic test results during the field evaluation

Diagnostic test	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Thermography (Highest temperature difference in °C)	3	2	2	3	2	2
Highest ultrasonic reading (dB)	0	0	0	0	0	0
Highest TEV reading (dB)	13	-	-	-	-	12

Based on online diagnostic test results, no defects were detected in the condition of the switchgears within the field trial period. In addition, the measurements are consistent for all data points. This indicates that there is no significant deterioration of the insulation and conductor components of the switchgear.

Switchgear performance assessment

The magnetic actuator driven switchgear was able to perform within the specified limits during switching operations. No problem was reported during the field evaluation period.

Technical assessment

The assessment of the technical aspects of the magnetic actuator driven switchgear are as follows:

1. **Compliance to existing technical specifications and standard practice.** There were several minor non-compliances to the standard practice which were detected during the Product Inspection tests by the certified Quality Inspector. All of these non-compliances were rectified prior to installation and commissioning.
2. **Ease of installation.** Difficulties were encountered by the cable jointers when cable jointing was performed during installation. This was caused by the arrangement of the cable bushings which was from front to back compared to the conventional arrangement from left to right. Figure 4 overleaf shows the illustration of the cable bushing arrangement as seen from the top view of the switchgear panels of both the magnetic actuator driven switchgear as well as the switchgear with conventional spring mechanism. In addition, the cable bushing height for the red phase in the outgoing panels was lower than 500mm causing further difficulty during cable jointing as 3 core cables were used in the outgoing panels.

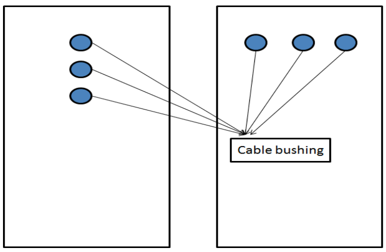

Figure 4. Cable bushing arrangement in the magnetic actuator driven switchgear (left) and air insulated switchgear with conventional spring mechanism (right)

3. **Ease of operation and maintenance.** Due to the fixed implementation of the circuit breaker, total shutdown is required when maintenance work and offline diagnostic tests are done on the circuit breaker. This is problematic especially during breakdown maintenance where only one panel is damaged but nevertheless requiring the whole substation to be taken offline. To deal with this problem, a the switchgear component arrangement needs to be redesigned whereby a three-position disconnector for isolating and earthing purposes is used in lieu of separate isolator and earthing switch. This change will allow the circuit breaker to be fully isolated from the busbar.

4. **Component reliability**. Jin et al. (2005) reported that the lifetime of electronic components of the magnetic actuator mechanism, such as the electronic controller unit and the capacitor, are dependent on the operating temperature. An increase in the operating temperature beyond the recommended maximum temperature of 40°C will severely diminish the lifetime of the components. Based on the temperature measurement during the field evaluation, the ambient temperature can go beyond this maximum temperature.
5. **Safety.** As the circuit breaker in the magnetic actuator driven switchgear are in fixed implementation rather than the in a withdrawable truck, accidents during rack-in and rack-out operation are totally prevented.

Financial assessment

A qualitative analysis on the life cycle cost components is shown in Table 3 below:

Table 3
Qualitative analysis on the life cycle cost components

Cost component	Impact of the cost component to the overall life cycle cost	Cost comparison with air insulated switchgear with spring mechanism
Purchase	High	At least 2.5 times higher
Installation	Low	Same
Operation	Low	Same
Condition monitoring	Low	Same
Periodic maintenance	Medium	Lower as grease maintenance of the spring mechanism is not required (i.e. shorter shutdown duration)
Breakdown maintenance	Medium	Higher as total shutdown is required even if only one panel is affected.
Spare parts	Medium	Higher as more expensive components are used.
Disposal	Medium	Same

Based on the life cycle cost analysis, the total cost of owning the magnetic actuator driven switchgear is much higher compared to the traditional switchgear. This is due to the higher purchase price, breakdown maintenance cost and spare parts.

CONCLUSION

Preliminary results indicated that magnetic actuator driven switchgear perform commendably on the safety aspect, on-site performance monitoring and online diagnostic test results. However, concerns such as difficulties during cable installation, need for total shutdown of the substation when performing diagnostic tests and circuit breaker maintenance, higher initial purchase price, and life span of the magnetic actuator mechanism need to be addressed. A review of the design needs to be made by manufacturers of this technology before they are widely adopted by utility suppliers.

ACKNOWLEDGEMENT

The authors would like to thank Tenaga Nasional Berhad for the funding of this research project.

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