Experimental Analysis of Detent Force and Static Thrust in a 3 kW Single-Phase Linear Permanent Magnet Generator for Striling Engines

Kyu-Seok Lee[1,2], Sung-Ho Lee[1], Jung-Hyung Park[1], and Jang-Young Choi[2]

[1] Senam Regional Division, Korea Institute of Industrial Technology, Gwangju 61012, Republic of Korea

[2] Department of Electrical Engineering, Chungnam National University, Daejeon 34134, Republic of Korea

MT 26 International Conference on Magnet Technology
Vancouver, Canada | 2019

• Abstract. **Linear generators are used in the free-piston Stirling engine due to the characteristics of the reciprocating mechanism. In addition, in order to drive the engine, the generator is driven using the motor mode. After the engine has been operated, it operates in the generator mode. For this reason, a single-phase linear permanent magnet generator (SPLPMG) suitable for reciprocating motion of a mechanism-driven type and a simple initial driving operation are applied to a Stirling engine. However, compared to rotating machines, it is not as easy to evaluate detent force and output power for a linear permanent magnet generator. In particular, it is important to evaluate the former because the generator includes a permanent magnet. It is also important to suggest a method for evaluating the output of the linear generator. Therefore, this paper proposes two methods. The first evaluates the detent force based on the manufactured SPLPMG, and the second assesses the static thrust by applying a direct current to the generator. A test rig was constructed to estimate detent force and static thrust, and tested using the evaluation system. The results were compared with those of the finite-element method. The comparisons confirmed that the FEM and proposed methods provide similar trends.**

INTRODUCTION

- When a linear drive system such as an FPSE is applied, the linear generator does not require a mechanical energy conversion device such as a screw or crankshaft,, and conferring it with a spatial advantage.
- However, due to the vibration caused by the reciprocating movement of the mover section, it is difficult to evaluate a linear generator with a short stroke length and 30 Hz over driving frequency. .
- Therefore, In this study, a direct current (DC) source is applied to an SPLPMG to estimate the output of the generator by evaluating the static thrust according to the location of the linear generator's movers.
- Finally, Detent force and static thrust for the SPLPMG was analyzed using the FEM, and the results of the analysis and evaluation method were compared by constructing a test rig system.

MACHINE STRUCTURE AND FEM RESULTS

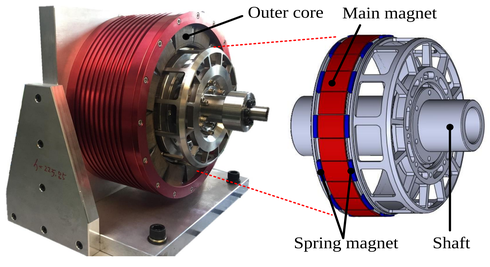

Fig. 1. Topology of the SPLPMG.

Table I. Dimensions and Design Specification

Parameter	Value
Output power	3 kW
Operation frequency	60 Hz
Rated load resistane	15 Ω
Airgap length	1 mm
Mover stroke	± 11 mm
Tuning Capacitor	70 uF

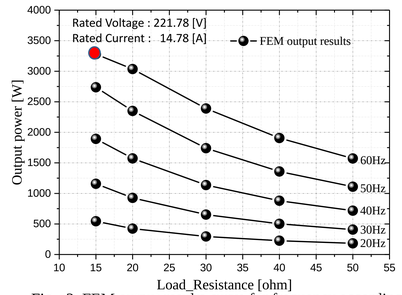

Fig . 2. FEM output results curve for frequency according to load resistance.

DETENT FORCE AND STATIC THRUST EVALUATION FLOW CHART

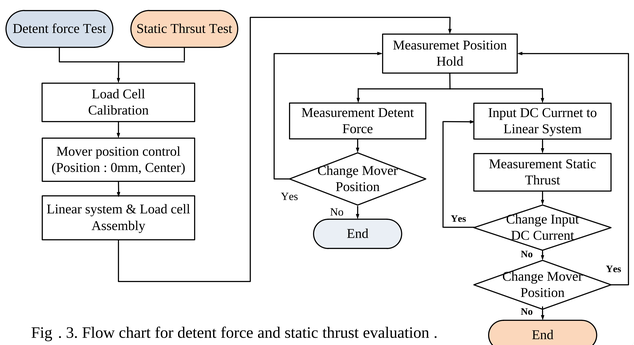

Fig . 3. Flow chart for detent force and static thrust evaluation .

DETENT FORCE ANALYSIS AND EVALUATION

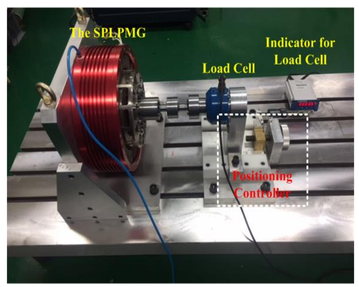

Fig . 4. Test rig for evaluating the SPLPMG's detent force and restoring force.

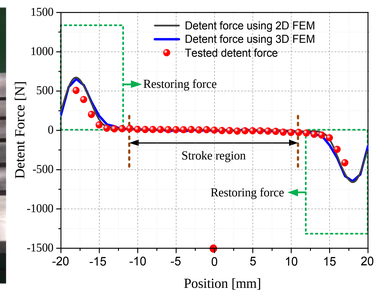

Fig. 5. Comparison of the results of detent force and restoring force.

STATIC THRUST ANALYSIS AND EVALUATION

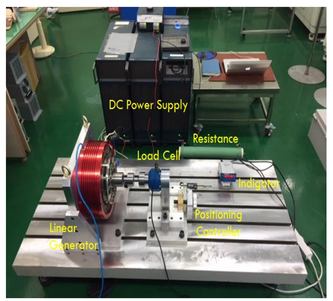

Fig. 6. Static thrust test rig.

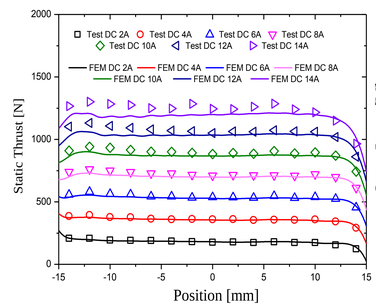

Fig. 7. FEM and test results of static thrust.

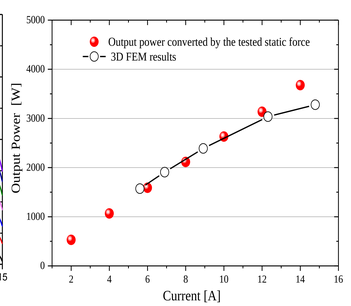

Fig. 8. Comparison of FEM results and converted output of static thrust.

CONCLUSION

- This paper presents a method to analyze and evaluate the detent force and restoring force of an SPLPMG.
- A test rig was produced, and the detent force and the restoring force were evaluated. The test results of the detent force and restoring force of the SPLPMG were similar to those of the 3D FEM.
- Also, the generator output was estimated by evaluating the static thrust according to the position of the movers while changing the DC current applied to the generator. When 14A DC current is applied to the generator, the thrust force is 1254.52N, and when converted to the output, it was experimentally confirmed that 3kW was exceeded.
- Also, a comparison of the output from the static thrust with that of the FEM-rated load analysis indicated almost similar results until the stator core reached saturation

Presented at the 26th International Conference on Magnet Technology , 2019 Sept. 22 – 27, Canada, Vancouver; Tracking ID: MT26-Wed-Mo-Po3.05-07