# Performance Test of Axial Turbine-Generator Magnet Permanent (ATPMG) On-Grid System Prototype for Very Low Head Application


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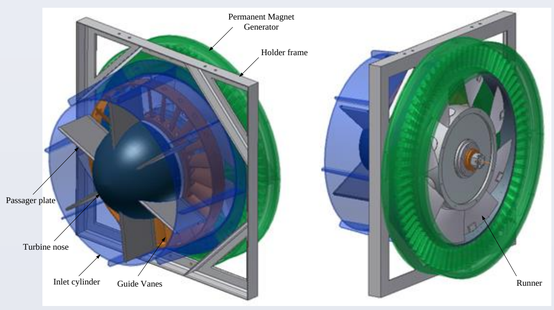
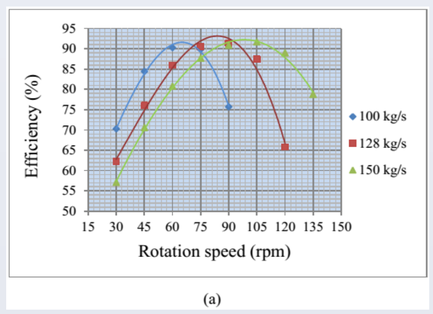
## ABSTRACT

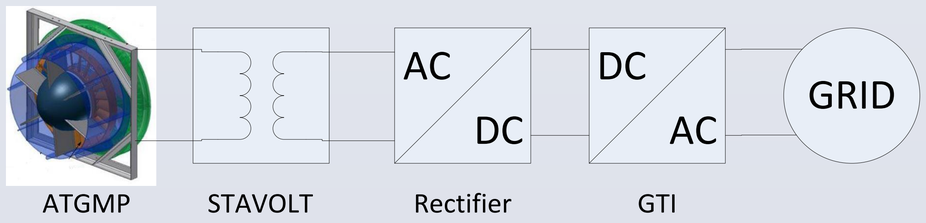

Many rivers which have large flow rate but low head, and Irrigation canals scattered throughout Indonesia are New and Renewable Energy (NRE) potentials whose the utilization is still very low. To promote and develop NRE utilization as power plant, the government has issued policy that allows the NRE power plant connect to the grid. This study is aims to investigate performance of on-grid hydro power plant system prototype that utilize very low head potential (<1m). The prototype system consist of Axial Turbine Permanent Magnet Generator (ATPMG) designed to operate at speed of 90 rpm, flow rate of 128 liters/second and head of 30 cm, generating AC power 300W at 220V 50Hz, connected to automatic voltage stabilizer to maintain the voltage at 220V. The AC to DC power was converted by diode rectifier with π filter to minimize DC voltage ripple, next connected to Grid Tie Inverter (GTI) which has MPPT to inject maximum AC power to the grid. The ATPMG was placed on an open water canal with cross section dimension 84x115 cm. Characteristic of ATPMG AC power, DC power before connected to GTI and on-grid operation on variation of flow rate range 0.199$m^3$/s to 0.326 $m^3$/s will be discussed in this paper. The highest on-grid system efficiency is 4.71% with maximum injected power to the grid of 37.37W, was achieved at flow rate of 0.270 $m^3$/s and head of 30 cm. The small efficiency and power of the system was caused by decreasing PMG performance in ATPMG.

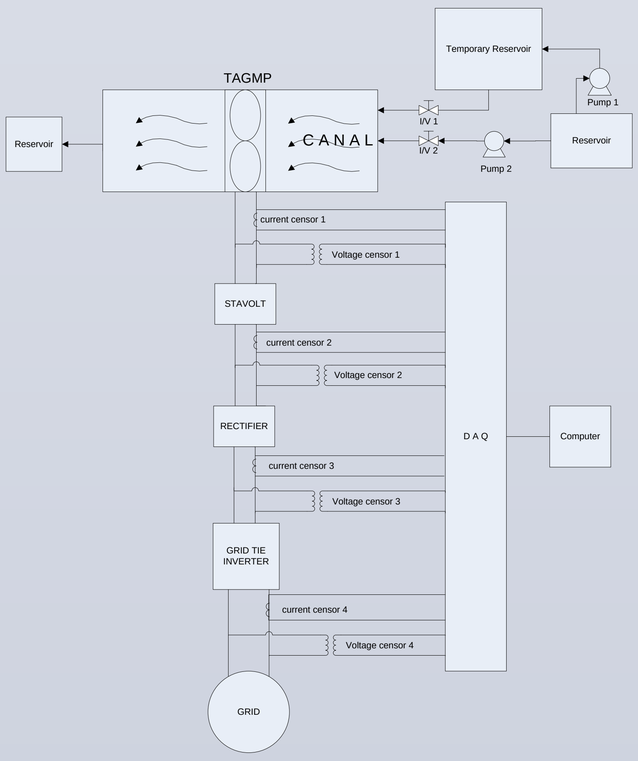

## TOPOLOGY OF THE ON-GRID SYSTEM OF AXIAL TURBINE-PERMANENT MAGNET GENERATOR (ATPMG)

The Axial Turbine-Permanent Magnet Generator (ATPMG) is an axial turbine integrated with a Permanent Magnet Generator (PMG) without transmission was designed to operate on head of 0.3 m, mass flow rate of 128 kg/s, rotation speed of 90 rpm with hub diameter was 0.6 m and tip diameter was 0.36 m [10]. The Permanent Magnet Generator (PMG) has 72 poles which generate electric power 50 Hz of frequency when rotor speed of 83 rpm and has been tested.




Automatic Voltage Stabilizer (STAVOLT) serves to stabilize the ATPMG output voltage at 220V.The STAVOL brand is Power LITE, servo motor voltage stabilizer type, 1000W power capacity with input voltage range is 150-250V. Rectifier serves to convert the AC output voltage STAVOLT to DC voltage before entering GTI. The Rectifier consists of diode rectifier which has maximum current limit 35A, with inductor 100 mH, 5 ampere and 2 ELCO capacitor of 450V/1000uF as π filter. The GTI which used is Solar River 1100TL-S from SAMIL Power which the specification is output AC power rating 1000W , grid voltage 230V, grid frequency 50Hz, Minimum DC voltage 80V, maximum DC voltage 500V and MPPT voltage range100-400V.

## RESEARCH METHODOLOGY



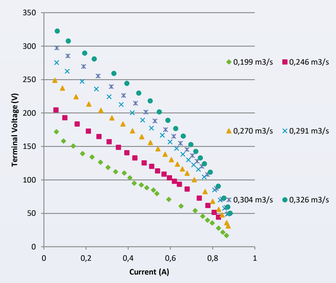

The ATPMG was placed on open water channel and positioned at a 45 ° to vertical axis. Water was pumped by 2 pumps from reservoir and the flow rate was controlled by arranging the opening of isolating valves. Three kind of testing performed: the ATPMG testing, DC power system testing and on-grid system testing.

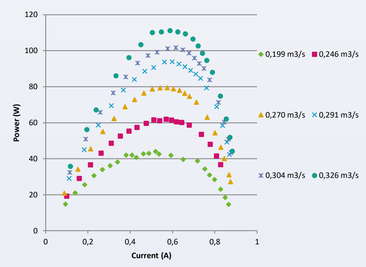
Constant flow test was applied to each testing with flow rate variations are 0.199$m^3$/s, 0.246$m^3$/s, 0.270$m^3$/s, 0.291$m^3$/s, 0.304$m^3$/s, and 0.326$m^3$/s.

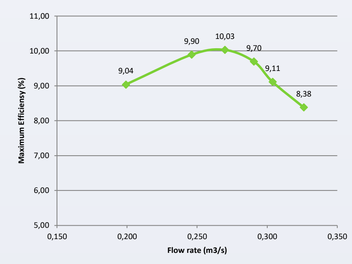
Some incandescent lamps were used to vary the load on ATPMG and DC power system testing. Output voltage and current of ATPMG, STAVOLT, Rectifier and GTI were measured by voltage and current sensors and recorded using data acquisition. The water level and water velocity were measured manually. The Experimental set-up of on-grid system test is presented in Figure side.

## RESULT

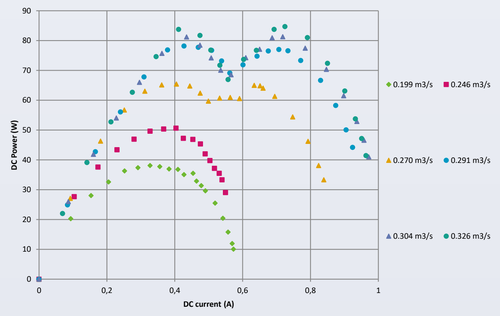
The maximum power generated by ATGMP at 0.199 $m^3$/s, 0.246 $m^3$/s, 0.270 $m^3$/s, 0.291 $m^3$/s,0.304 $m^3$/s, and 0.326 $m^3$/s were 44,10 W, 62,04 W, 79 , 57 W, 93.89 W, 101.78 W, and111.19 W respectively. But from Figure below, the highest ATPMG efficiency was10.03% was achieved at 0.270 $m^3$/s of flow rate. These result if compared with test result, the ATGMP performance has been decrease.

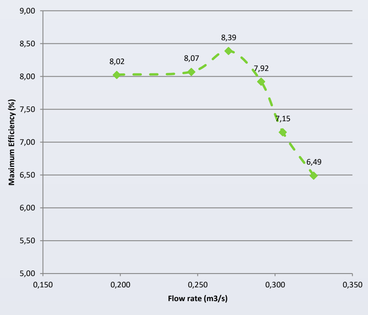


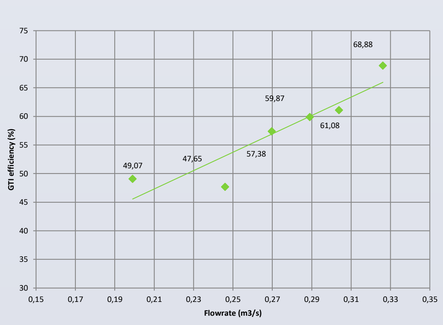

### DC Power System (ATPMG-STAVOLT-Rectifier) Test Result

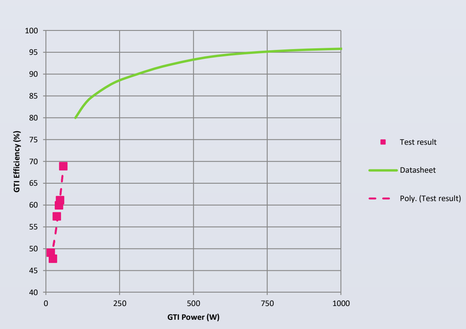


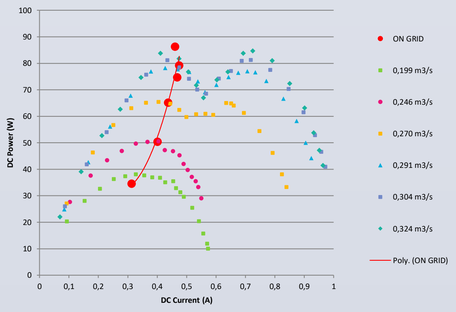

Shown that at every flow rate has maximum DC power also. At flow rate 0.270$m^3$/s, 0.291$m^3$/s, 0.304$m^3$/s, and 0.326 $m^3$/s, the power has two peaks due to STAVOLT activity. From Fig 4.b known that the highest efficiency of DC system was 8.39% obtained at flow rate 0.270$m^3$/s with efficiency of ATPMG 9.3%, STAVOLT efficiency 97.35% and Rectifier efficiency 92.72%.

### On-Grid System (TAGMP-STAVOLT-Rectifier-GTI) Test Result




From On-Grid testing, the efficiency of GTI on every variation flow rate are shown in Figure above. The GTI efficiency values in the figures are small if compared with efficiency value which mention in the GTI specification sheet. This is normal because the GTI power output is far from its capacity. Inverter efficiency depend on ratio inverter output power with its capacity.



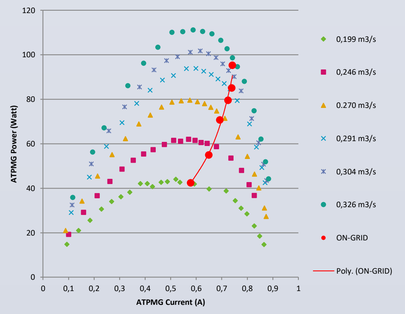




Figure above is shown that the MPPT in the GTI worked well. The on-grid system can operate at its maximum DC power in every flow rate. But from Figure above right known that at flow rate 0.246 $m^3$/s, 0.270 $m^3$/s, 0.291 $m^3$/s, 0.304 $m^3$/s, and 0.326 $m^3$/s, the system did not operate at maximum power of ATPMG.

## CONCLUSION

Performance test of on-grid system prototype consist of a very low axial head turbine integrated with a permanent magnetic generator (ATPMG), Automatic Voltage Stabilizer (STAVOLT) servomotor type, Rectifier and Grid Tie Inverter (GTI) with flow rate variation 0.199 $m^3$/s to 0.325 $m^3$/s has been discussed in this paper. ATPMG and DC power systems test before connected with GTI are also performed to compare the power produced between before and after on-grid. Based on the test results, the on-grid system performance is small due to performance of the PMG has decreased. The decrease in ATPMG performance also affects to efficiency of the GTI because the GTI does not operate on its power rating. The on-grid system does not work at the maximum power of ATPMG at flow rate above 0.199 $m^3$/s. However, the system can deliver power to the grid at its maximum DC power.

## ACKNOWLEDGEMENTS


This research is supported part from the Research Center of New and Renewable Energy LPPM Institut Teknologi Bandung and Research Center for New and Renewable Energy and Conservation Energy, Ministry of Energy and Mineral Resources, Indonesia