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An Effective Method to Measure Total Input-Output of a Co-Generated Electric System

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Abstract

The Gamma Manager Ltd Laboratories developed and patented recently a new rotating machine which has non-conventional geometry and structure and is capable to generate electricity and to utilise the relatively large iron losses in the form of heat. Due to the dependence of iron losses on various parameters, there was a thermo-box (T-box) method developed: the T-box which is made of insulating material incorporates both the three-phase induction motor and the new C4 unit. Heat equilibrium provides chance to measure the volume of input and output water of a heat exchanger. The leakage of the T-box is also determined by another test and a regression equation was established. Thousands of such tests presented that total power output exceeded power input by 4 to 6%

1. - INTRODUCTION

Gamma Manager Ltd in co-operation with its parent and sister companies located in the US, Canada, UK and Hungary have developed a non-conventional rotating electrical machine for heat and electricity generation which has a new geometry. Due to the design, its iron loss is usually much larger than the conventional one and depends not only on the usual parameters, but changes rapidly with the increase/decrease of various currents, too. Thus, the usual no-load and short-circuit (rotor-blocked) tests can not be used.

The term co-generated electric system comes from the fact that the relatively large iron loss can be utilised as heat by various means and on the other hand, electricity, which provides almost pure sinusoid, plays vital role. Depending on the demand the ratio of heat and electricity can be varied, thus either more heat or more electricity can be generated. In such a way the heat can be utilised in a direct way.

The rotating machine (Fig.1.) is called as C4 unit where the letter C refers to the co-generated system and the number 4 means the fourth series in the family. Its weight is 1,500 kg and is driven by a three-phase induction motor, thus the unit serves as a miniature power plant. It goes without saying that any customary diesel or turbine prime mover can also drive the C4 units.

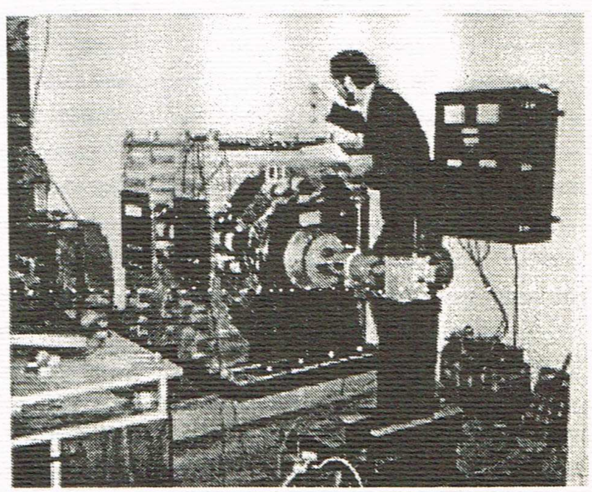

Fig.1. C4 unit: the co-generated electric rotating machine

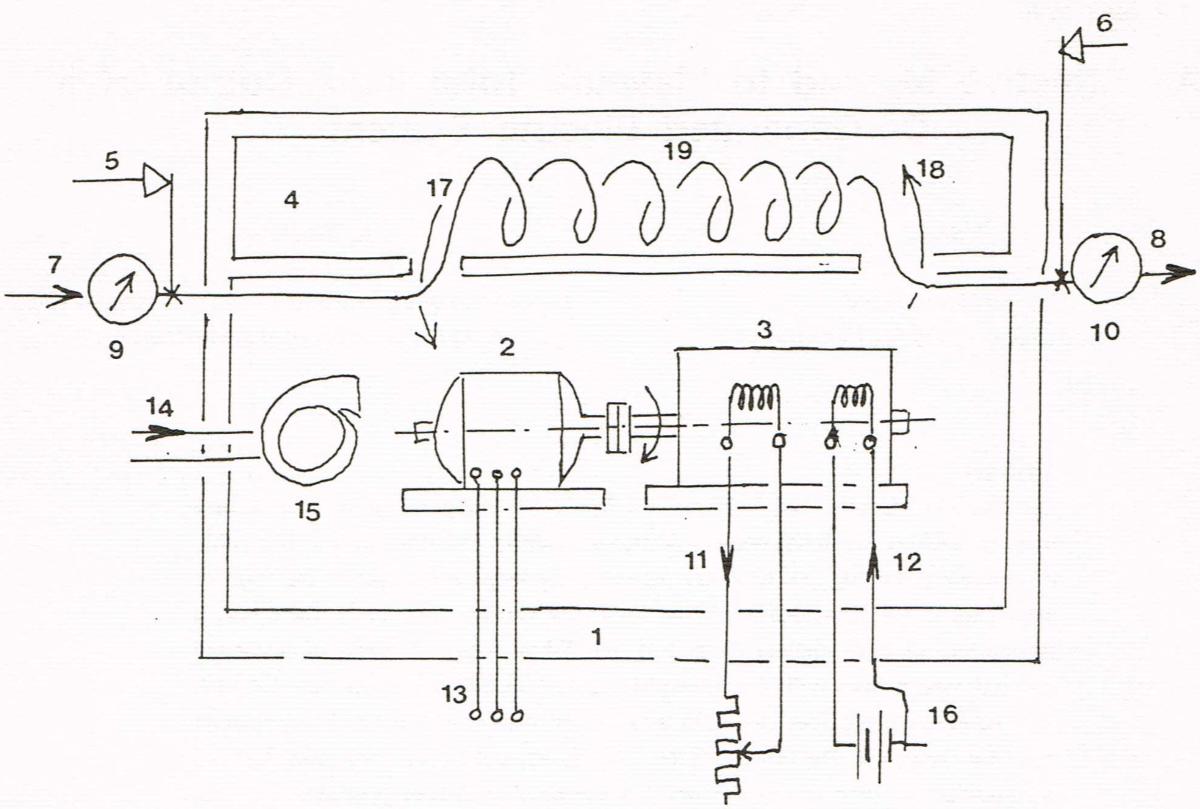

Fig. 2. T-box test arrangement. *1* - T-box, *2* - three-phase induction motor, *3* - C4 unit, *4* - heat exchanger, *5* - "temperature in" measurement in ^{O}C, *6* - "temperature out" measurement in ^{O}C, *7* - tap-water input, *8* - warm-water output, *9* - water-flow input measurement in m^3 per hour, *10* - water-flow output- measurement in m^3per hour, *11* - power output, *12* - d.c. excitation power input, *13* - three-phase power input, *14* - blower power-input, *15* - air-blower, *16* - d.c. battery or d.c. power supply, *17* - air-flow out, *18* - air-flow in, *19* - water pipe coil in heat exchanger.

All types of losses can not be measured in the usual ways because of the non-conventional geometry and performance, therefore a simple, efficient, and to some extent, a pedestrian testing method was developed. This paper presents the testing method which focuses the measurement of power input and output rather than the usual loss-measurements. Although the measurement method was designed in an accurate way and thousands of tests have been performed, plus the method is computerised, a "technological paradox" appears. This paradox presents an unusual fact, at well-determined technical environment i.e. with parameters defined, that the output to input ratio exceeds the unity by 4 to 15%.
This paradox can be attributed either to the testing method or to the non-conventional geometry which was developed by the laboratory and patented in several countries indicating the highest efficiency ever achieved.

2. - T-BOX AS A HEART OF THE INTEGRATED TEST

1. In order to verify or disprove the results which can also be obtained by torque metering, a so-called "thermo-box" or shortly "T-box" test method was developed (Fig.2.).
The T-box (1) was built from commercially available heat insulating material and both the three-phase induction motor (2) coupled to the C4-unit (3) were placed inside the T-box, together with a water-air-type heat exchanger (4). The water input temperature (5) and

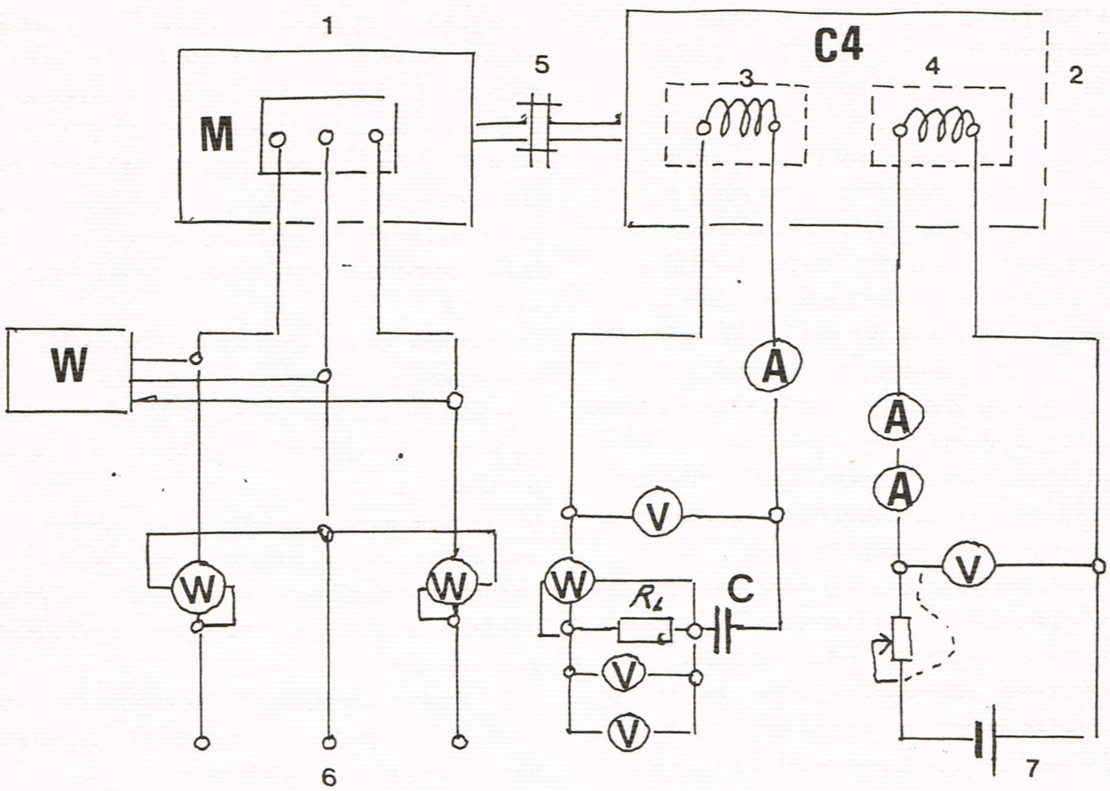

Fig.3. Schematic diagram of the T-box integrated test. *1* - three-phase induction motor, *2* - C4 unit, *3* - armature windings, *4* - excitation windings, *5* - coupling, *6* - 3 x 380 V, 50 Hz power supply, *7* - d.c. excitation (batteries).

output temperature (6) were measured continuously by sensitive ohmic temperature gauges; two gauges, each, are located on both sides. The volume of the fresh input tap water in m^3 per hour (7) was measured by a calibrated turbine volumetric meter (9) and the volume of the output warm water was also measured by a meter (10) and of course, (9) and (10) had to agree.

The electrical power output (11) of the C4-unit was dissipated on the ohmic load, and the d.c. excitation power (12) was supplied from a battery or a d.c. power supply. The induction motor (2) was powered by a three-phase, 50 Hz network (13). The air inside the T-box was well circulated with two air blowers (15) and they were supplied from the network (14).

It should be noted that the volume of the water input-output was measured in two further ways: in addition to the calibrated turbine volumetric gauge: namely by an ordinary water meter and by filling up from the tap a can of known volume and measuring the time to fill-up the can.

2. The whole system described above was computerised and all relevant data were printed out every 10 minutes or every 30 minutes, or as frequently as it was needed.

3. For comparison purposes to the C4 unit, to test a commercial synchronous generator unit approximately of the same size the C4 unit was simply removed from the T-box and one by one the new units with the driving motor were placed into the T-box and the tests were carried out using identical instruments and methods.

4. Fig.3. presents the schematic diagram of the measurement systems indicating the units and the measuring instruments as well. It is well worth mentioning that the computer-based data-acquisition system is not indicated in the diagram.

3. - THEORETICAL BACKGROUND AND PERFORMANCE OF THE INTEGRATED TEST

1. One complete test usually took 150 to 180 minutes to have heat equilibrium depending on the initial ambient temperature. The test stops when the difference of water output and input temperatures remains constant at a given water flow through the T-box. At this point the total generated heat energy per unit of time inside the box is equal to the heat energy per unit of time leaving the box through the water pipe, provided that the total electric power input and output at this point in time are also constant at constant rotational speed of the units. This is the time when the system inside the T-box is in equilibrium regarding the heat performance.
2. The total losses of the system generate heat inside the T-box which are composed of (a) mechanical losses and ventilation losses, plus (b) iron and copper losses.
3. The following demonstration utilises the average figures obtained from several hundred tests.
4. The so-called C4 geometry produced an energy output to input ratio paradox under numerous repeated controlled test using certain parameter combinations in the armature circuits, such as various loads, direct excitation currents and alternating load currents, capacitor sizes, mechanical loads on the shafts, and so on.
5. Using the C4 units and numerous other benchmark units, the following combinations were investigated both in dynamic and static way:
(a) stators with 4 poles and rotors with 2 poles;
(b) same as (a) except rotors with 4 poles;
(c) same as (b) above with distinctly two different sub-combinations, namely:
(i) when rotors had coils, and
(ii) when rotors had no coils.
6. From the above list only (b) are discussed in some detail. as all the other combinations exhibited similar anomalies with respect to the obtained output to input ratios. At certain deliberate parameter setting the output to input ratios were either significantly above or below the expected value of unity. In other words, the sum of the power input was significantly more or significantly less than the power output.
7. Testing methods
(a) When d.c. excitation current flowing in the excitation coil and the rotor is rotating with n a voltage can be measured at the terminals of the armature coil and when the armature circuit is closed with R_L ohmic load an *i* load current will flow and $i^2xR_L = P_{out}$ (Watt) useful load is dissipated or consumed on the R_L load. Thus nothing unusual happened one might say, unless a torque meter is placed onto the shaft of the rotor to measure the input mechanical power $P_{in}=T\omega$ (Watt), where T is the torque in Newton-metre and ω is the mechanical angular speed measured.
(b) To more closely investigate the anomalies "slow-motion-picture" type operation called the "static test" were performed. This simply means the following:
(i) to excite the unit by the excitation coil from a d.c. power supply;
(ii) to simulate a sinusoid type a.c. current in the armature coil with the appropriate phase angle using an independent external power supply which feeds *i* current into the armature coil with the required amplitude at the given rotor positions;
(iii) to rotate extremely slowly or rotate the rotor around by 1^{o} or 2^{o} steps at a time and record and sum-up the measured torque during a full cycle;
(iv) to evaluate the result and compare it:
(A) to an identical dynamic test result when the rotational speed "n" is the usual, say 1000 or 1500 rpm, and
(B) to a static test result using identical test parameters with commercially available "off-the-shelf" electrical generator, i.e. with an energy converter.

8. At equilibrium the water carries out the following heat performance from the box P_H in kilowatt and it can be computed as:

(I) $P_H = \frac{dm}{dt} \times c_{water} \times \Delta\theta_{water} = 10.415$ W

(ii) $\frac{dm}{dt} = 0.218055$ is the mass flow per unit of time

(iii) $c_{water} = 4.19$ is the specific constant of the water

(iv) $\Delta\vartheta_{water} = \vartheta_{out} - \vartheta_{in} = 11.4\ ^{o}C$

(b) The "useful" power output on the ohmic load is P_{out} = 22,100 kilowatts,

(c) P_L is the heat leakage going out from the box (1,925 W)

(d) the components of the total input power in kW are as follows:

(i) $P_{in\ mot}$ refers to the driving motor (31,800 W)

(ii) $P_{in\ blow}$ refers to the blowers, measured separately and was found constant (1,000 W),

(iii) $P_{1\ in}$ is the a.c. component of the excitation circuit which is measured directly and also computed separately (230 W).

The measurement method of the leakage of the T-box P_L follows the same process as described in the previous section with only one exemption the power output circuit (11) shown in Fig.2. is closed with capacitors and sufficiently large, so that the heat energy produced inside the T-box is identical or very close to the heat energy produced under the load test.

Based on hundreds of identical tests it was found that the leakage of the box in watts versus $P_{water\ out}$ in kilowatts meets the following linear equation:

$$P_L = 3415 P_{water\ out} - 1420 \qquad (1)$$

for the T-box in question it was found that P_L = 1,925 watts.

(e) The total power input can be computed as:

$$\Sigma P_{in} = P_{in\ mot} + P_{in\ blow} + P_{1\ in} \qquad (2)$$

$$= 31{,}800 + 1{,}000 + 230 = 33{,}030 \text{ W}$$

(f) The total power output will be available from the following equation:

$$\Sigma P_{out} = P_{out\ mot} + P_H + P_L \qquad (3)$$

$$= 22{,}100 + 10{,}415 + 1{,}925 = 34{,}400 \text{ W}$$

(g) Thus, we found that the difference between power input and output is 1,410 watts as an average.

4. CONCLUSION

A. Based on several hundreds of accurate tests the results obtained are as follows:

(a) By deliberate setting of the parameters the larger 1500 kg C4 unit deviated significantly from the traditional energy balance;

(b) As expected, the commercial off-the shelf energy converter unit did not deviate from the customary energy balance.

B. Based on a rather large number of test results with numerous different sized of bench-mark test devices similar to the C4 unit and based on the observations the following can be stated relative to the output/input ratios of the C4 type units:

the output/input ratio increases with the mass of the active iron employed, with the diameter of the rotor and with the rotational speed of the unit.

5. - ACKNOWLEDGEMENTS

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REFERENCES

Patents, reports, papers and lectures for C4 units between 1992-1995.