# Investigation of an Autonomous Hybrid System for Direct Supply of an Induction Heating Device

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***Abstract* – The paper presents an autonomous renewable energy hybrid system for supplying an induction heating device. The system realizes direct supply of the inverter device by the converted wind and solar energy, thus omitting the necessary 50 Hz DC-AC converter for energy injection in the grid. The discussed approach is applicable for other industrial systems. The realized DC-AC converter operates at increased frequency and combines the requirements of both the supply RES and the induction heating load.**

***Keywords* – Wind and solar energy conversion, induction heating.**

## I. INTRODUCTION

Renewable energy sources (RES) are the alternative for more and more depleting fossil fuels. A specific application of RES is for supplying induction heating systems. This combination, described in [1, 2, 3], based on transistor converter with increased frequency, does not require the usage of a specialized inverter. In this case it is necessary to match the power and the voltage of the source and the load.

The goal of this article is to investigate an autonomous hybrid system, built from wind generators and photovoltaic panels, for direct supplying an induction heating converter. The advantages of the system should are:

- Removing of the standard inverter. This simplifies the whole system and reduces its price. This requires realization of technical solutions which allows direct supplying of the converter form the RES system.
- The output parameters of the converter (*I, V , P, cosφ*) are according to the requirements of the used inductor. The working frequency is selected according to contour resonant frequency.
- The converter is built for each specific case with the following capabilities: sinusoidal output voltage is not obligatory and no system for synchronization and parallel work with the power grid is required.
- Additional blocks of the system – thermo sensor, temperature controller, frequency synchronization system, automatic control and others – are part of the converter.

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## II. INVESTIGATION OF THE PROPOSED SYSTEM

Block diagram of the test system is shown in Fig.1a and the detailed scheme in Fig.1b. The system is build upon the classical topologies [4, 5, 6]. Two energy sources are used: wind generator (WG) and photovoltaic modules (PV). They generate two different voltages $V_1$ и $V_2$, connected to particular DC/DC converters. They should fulfil the following requirements:

- Output voltage stabilization to a specified value;
- Proportional distribution of the loading according to the power capabilities of each energy source;
- Protection in non nominal modes
- Control from a single clock generator, because of the problems.

Taking into account the specific characteristics of each energy source the schematics of the converters are chosen:

- The wind generator is a construction that does not allow modification of the schematic (correction of the output voltage) and a full bridge converter topology is used.
- The photovoltaic modules allow random way of connection (thus different output voltages and currents) and a topology with center tap transformer is used.

Fluctuations of the supplied voltage require the transformer calculation to be done according to the maximum value of the voltage. The following equation is used:

$$V = 4 k_f \, f \, w B_r \, S_{fe}, \qquad (1)$$

$$w S_{fe} = \frac{V}{4 k_f \, f \, B_r} \qquad (2)$$

where: $V$ – voltage; $w$ – number of turns; $S_{Fe}$ – cross section area of the magnetic core; $f$ – frequency; $B_r$ – magnetic induction; $k_f$ (in this case $k_f=1$).

The ratio between $w$ and $S_{Fe}$ is selected by technology and construction requirements and in compliance with the nomenclature of the manufactured magnetic cores and copper wires.

Equation (2) is used to design all transformers in the system. As a result the filter capacitor $C_f$ is calculated by:

$$C_f = \frac{1}{2.m.f.R_d.K_n} \qquad (3)$$

where: $m$– number of phases; $R_d$ – load resistance, $K_n$– pulsation coefficient.

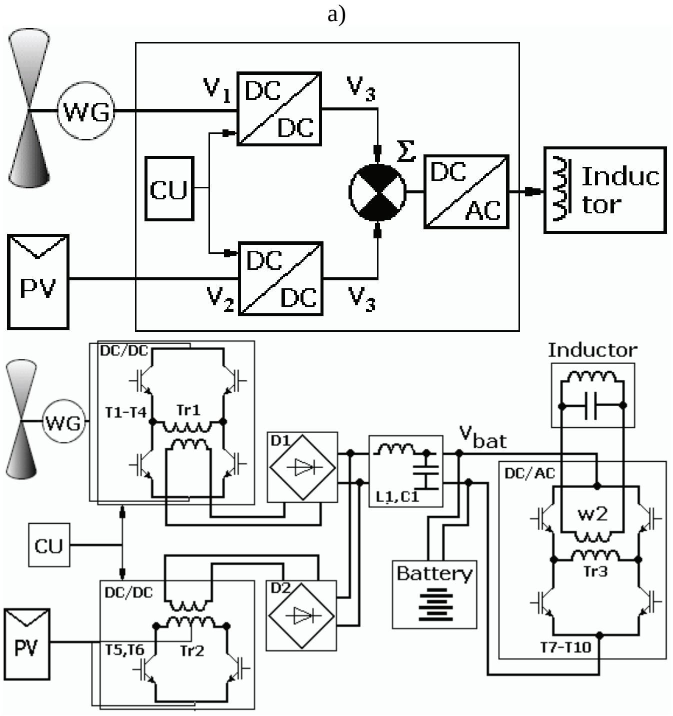
The sum of both voltages is fed into the input of the DC/AC converter. This converter operates within the frequency range of 25-35 kHz. This frequency is selected by the specific technology requirements of the heating process.

In the test system IGBT transistors are used for the DC/DC and DC/AC converters. A standard UPS system working in on-line mode is built. The investigation of the influence of power change of the load is done by changing the number of turns of the output winding $w_2$ of the transformer *Tr3* in Fig. 1b at a fixed input voltage (from the energy sources) $V_{Bat}$=180V at maximum power $P_{RES} = 2000$ W.

According to power of the load and the power of the RES, there are three possible cases:

- The power of the load is less than the maximum power of RES - $P_{LOAD} < P_{RES}$ ;

a)




b)

Fig.1 Block diagrams of the induction heating converters powered by RES, a); Detailed scheme, b).

- The power of the load is approximately the same as the maximum power of RES $P_{LOAD} \approx P_{RES}$ ;
- The power of the load is more than the maximum power of RES - $P_{LOAD} > P_{RES}$ .

According to these conditions there are three operation modes:

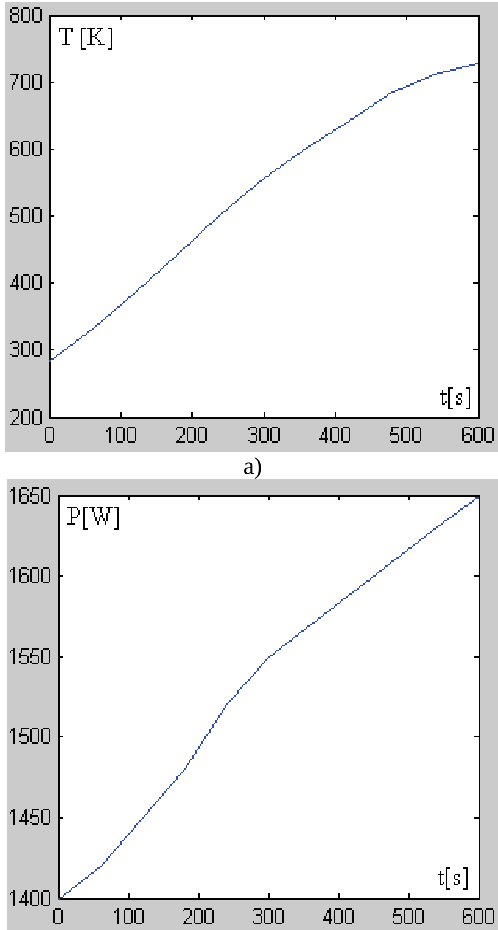
1. When $P_{LOAD} < P_{RES}$ there are no restrictions and the operation of the two blocks RES Supply and Load are independent.

Experimental results are shown in Fig. 2 and Table I. The initial power of the load is $P_{LOAD}=1400W$.

TABLE I
EXPERIMENTAL RESULTS AT $P_{LOAD}$=1400W

| t | s | 0 | 60 | 120 | 180 | 240 | 300 | 360 | 420 | 480 | 540 | 600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T | K | 285 | 332 | 386 | 443 | 503 | 557 | 602 | 643 | 684 | 712 | 728 |
| P | W | 1400 | 1420 | 1450 | 1480 | 1520 | 1550 | 1570 | 1590 | 1610 | 1630 | 1650 |

2. When $P_{LOAD} \approx P_{RES}$ it is necessary to control the load because its ability to increase the power with increasing the temperature of the heated object. The experimental study of this case is done by increasing the voltage of *w2*. If the load



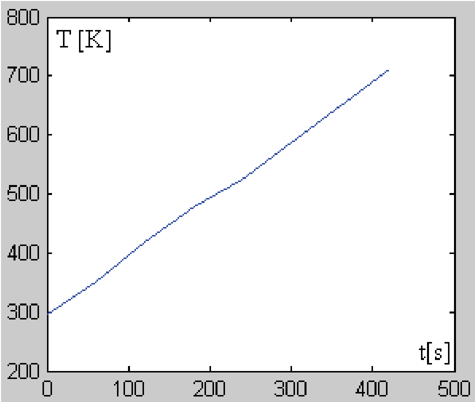

b)

Fig.2. Transition process at induction heating of a hollow aluminum cylinder when $P_{LOAD} < P_{RES}$ :
a) temperature versus time *T = f(t)*;
b) power versus time *P = f(s)*

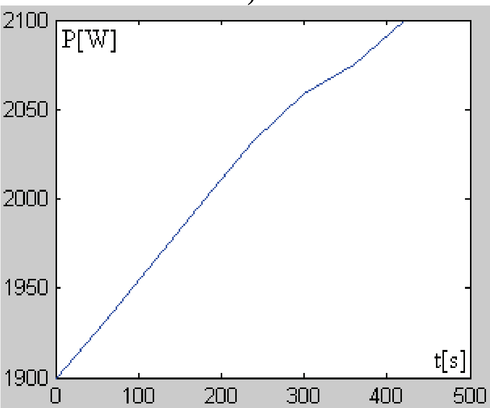
power is $P_{\kappa} = 1900 \div 2100$ W, than this overloads the RES supply. The experimental results of the temperature and time in this mode are shown in Fig. 3 and Table II.

TABLE II
EXPERIMENTAL RESULTS AT $P_{LOAD}$=2100W

| t | s | 0 | 60 | 120 | 180 | 240 | 300 | 360 | 420 |
|---|---|---|---|---|---|---|---|---|---|
| T | K | 297 | 351 | 419 | 477 | 524 | 586 | 649 | 713 |
| P | W | 1900 | 1931 | 1966 | 2000 | 2033 | 2059 | 2075 | 2100 |




a)




b)

Фиг.3. Transition process at induction heating of a hollow aluminum cylinder when $P_{LOAD} \approx P_{RES}$ :
a) temperature versus time $T = f(t)$;
b) power versus time $P = f(s)$

3. The case when $P_{LOAD} > P_{RES}$ should not be allowed for continuous operation. In repeating short time mode it is necessary to monitor the temperature of the components. In this case the goal is to reach and maintain the maximum working temperature of the components. Experimental verification should be carried out for each case.

## III. Conclusion

An autonomous renewable energy hybrid system for supplying an induction heating device is realized and discussed. The advantage of the system is omitting the necessary 50 Hz DC-AC converter for energy injection in the grid by the direct supply of the inverter heating device by the converted wind and solar energy. The discussed system is realized with standard switches and components.

The approach is applicable with benefits in other industrial systems.

## Acknowledgement

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