HYBRID POWER SUPPLY OF THE AGROKAPILARIS® SYSTEM FOR IRRIGATION OF VEGETABLE CROPS ON THE PLOT "GRABOVAC" – OBRENOVAC

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Abstract: The paper presents the design and implementation of a hybrid power supply system used in the "Agrokapilaris®" system, for irrigation of vegetable crops on the experimental plot of the Secondary Technical Agricultural-Chemical School from Obrenovac, at the location of the village Grabovac. The hybrid power supply system is based predominantly on the use of renewable energy sources (wind and solar) with the use of a battery bank, and an electronically controlled fast static switch is additionally realized, which, if necessary, ensures switching the system electrical distribution network 230V, 50Hz. The results presented in this paper are part of the results of the project "Natural resources of wind and water in order to improve agro-technical measures of irrigation: application of green technologies in the function of sustainable rural development of Serbia", within the Incentive Program for improving the creation and transfer of knowledge technological, applied, development and innovative projects in agriculture and rural development in 2019. The project is funded by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia.

Key words: Hybrid power, wind, solar, electrical grid, power electronics, agriculture, irrigation, sustainable

1. INTRODUCTION

Agriculture is the real and only source of food for people. Most agricultural machinery is based on fossil fuels, which contribute to the "greenhouse" effect due to the emission of gases and as a result, climate change is accelerating. Such damage to the environment can be mitigated by promoting renewable energy sources (RES), such as primarily solar energy, wind, biomass, tides, geothermal energy, hydropower, biofuels and wave energy. Most of these renewable sources (primarily sun and wind) have a very large potential for the agricultural industry, and state policy subsidies should encourage farmers to use RES technology [1-3].

Wind energy in combination with solar energy are one of the most commonly used hybrid power supply systems for various purposes, which relate to the application and improvement of agro-technical measures in irrigation systems. The advantage is the fact that in periods when there are lower intensities of solar radiation (late autumn, winter or early spring), wind energy dominates. Also, in the summer period (which otherwise implies the dominant energy of the sun), especially in mountainous areas, but often in plains, and at night when there is no solar energy, wind energy becomes dominant.

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In this way, the supplementation of these two types of renewable energy has been achieved, so that on an annual level there is an almost continuous system that can provide power supply to the irrigation system for agricultural crops.

Additional improvement of the irrigation system can be achieved if the electrical grid 230V, 50Hz is used as an additional energy source [4-6]. In that case, it is a hybrid power supply system for irrigation of agricultural crops. One of the important features of this power supply system is that under certain conditions it can be a continuous source of energy.

The tendency of the user is to use the electrical grid as a source of energy as little as possible and only when it is necessary, and to use as more as possible, renewable, clean, or so-called "green energy". It should be noted that in these systems, a storage of electric accumulators (batteries) is necessary, which serves to accumulate renewable energy (in this case, wind and solar energy). This storage system is popularly called a "battery bank". So, battery bank should provide power for to irrigation and watering systems, in periods when there is not enough energy from wind and sun.

Hybrid power supply systems (HPSS) are energy systems that contain more than one power source. In general, HPSS supply consumers with electrical energy, which is obtained mainly from RES [6], [7-9]. These systems usually consist of wind turbines with generators, solar panels, hydro-generators, and in some cases when greater power autonomy is required, diesel electric generators (DEG) or gasoline electric generators (GEG) are added as auxiliary power sources [5], [10-11].

The use of these generators is associated with problems of installation, assembly, ventilation and drainage of fuel combustion products, and therefore with significant pollution of the surrounding air. Also, these electrical generators make significant noise and vibrations, and therefore effect on the environment, especially humans and animals. For these reasons, the electrical grid can be used as an additional power source. In this way, the mentioned HPSS become uninterrupted, which is very important from the aspect of application of modern methods and techniques in irrigation systems of agricultural crops.

This paper presents an example of application and implementation of a system for pumping water and irrigation of vegetable crops according to the system "Agro Kapilaris®" on the school plot of the Secondary Technical Agricultural-Chemical School from Obrenovac, at the location of the village Grabovac. The basic idea in the realization of the project was to use as much as possible renewable and nature-given "green energy". In cases where there is a decline in production from renewable sources and/or the discharge of the battery bank, the primary power source becomes the electrical grid.

2. IRRIGATION METHOD AGRO KAPILARIS®

The "Agro Kapilaris" irrigation system is a method of sub-surface capillary irrigation in which the basic principle is to distribute water to the plant roots by specifically constructed water transmitters, which are installed below the depth of tillage [12-13]. A general overview of this irrigation system is given in Figure 1.A schematic representation of this irrigation system is given in Figure 1.

The water transmitters are located at a depth of thirty centimeters, so that the water is delivered directly to the root. It is a system of underground channels that always keep the water at a certain level and the water moves capillary through the soil, radially upwards and sideways, and this is what gives the plant the ability to feed from the soil [12].

There are three main characteristics that separate the "Agro Kapilaris" system from all other existing irrigation systems: (1) operation under extremely low pressures (in terms of energy efficiency, it stands out as the most economical, because no other existing irrigation system operates at an operating pressure of 0.2 bar), (2) long service life of the system (no clogging of the water transmitters, which is a prerequisite for long service life), (3) self-regulation when giving moisture to plants (no other existing irrigation system has this option).

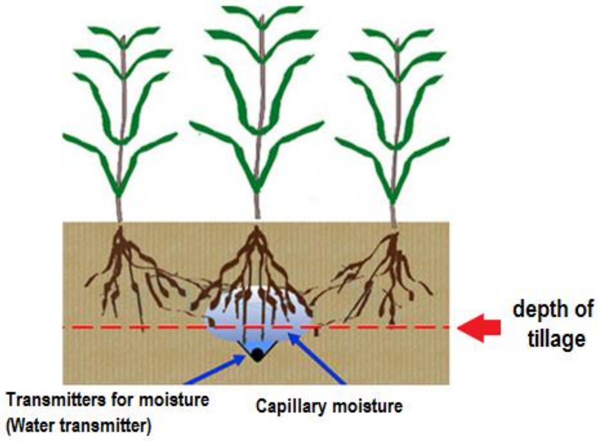

Figure 1. Principle of Agro Kapilaris® irrigation system

In addition to these three most important advantages, there are others that are very important and that favor this method of irrigation: suitable for use in organic and ecological production, reduces the risk of diseases and pests, is applicable to small plots (even irregularly shaped), as well as on large complexes, easy and simple use and maintenance of the system, through the system it is possible to perform fertigation with organic or microbiological fertilizers, through the system it is possible to perform fertigation with water - soluble mineral fertilizers according to the "Global GAP" system.

3. HYBRID POWER SUPPLY SYSTEMS

HPSS are mainly found in the form of the three most common topologies: (1) centralized "AC bus", (2) distributed "AC bus", (3) centralized "DC bus".

The centralized "AC bus" topology is shown in Figure 2. In this case, the generators (solar, wind and diesel) and the battery are installed in one place and are connected to the main AC bus before being connected to the grid.

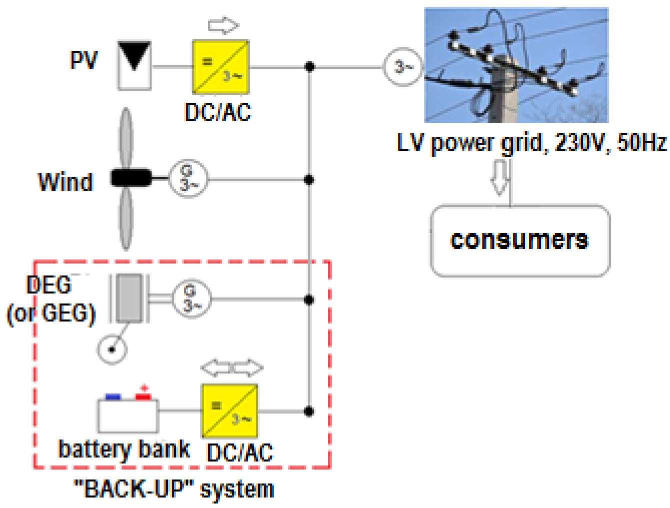

Figure 2. Principle of the centralized "AC-bus" topology of hybrid power supply to consumers

This system is centralized in the sense that all the energy conversion systems and batteries delivery power to the AC electrical grid at the connection point. In this case, the power produced by the PV system and the battery is converted to alternating current by means of a DC / AC converter (inverter) before it is delivered in the AC grid.

Energy conversion systems can also be connected to the grid in a decentralized manner as shown in Figure 3.

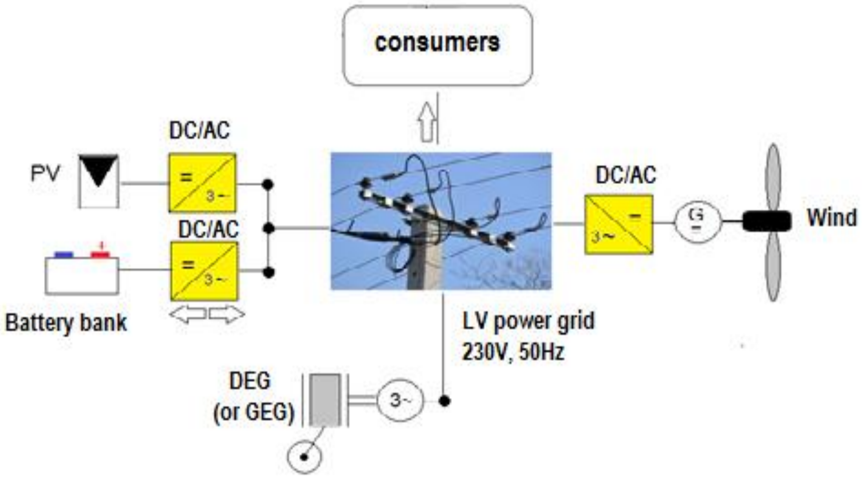

Figure 3. Principle of the distributed "AC-bus" topology of hybrid power supply to consumers

The power supplies in this topology do not have to be installed close to each other as in the case of the topology in Figure 1 and do not have to be connected to one main bus. The power produced by each source is individually adapted to the requirements of the AC network.

The third topology shown in Figure 4 uses the main centralized DC bus. Thus, energy conversion systems that produce alternating current, i.e. the wind generator and the diesel (or gasoline) generator, first deliver their power to the rectifiers to be converted to DC before being delivered to the DC main bus. The main inverter takes responsibility for powering the AC mains from these main DC buses.

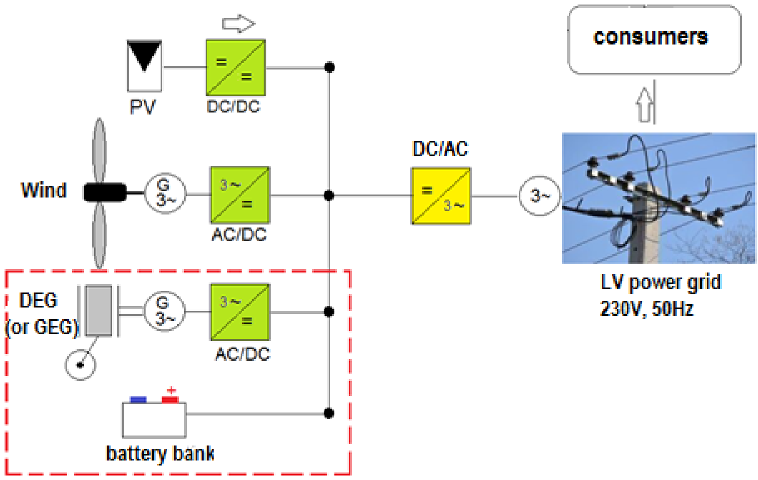

Figure 4. Principle of the centralized "DC-bus" topology of hybrid power supply to consumers

In recent times, systems with the so-called centralized "DC-bus" power supply topology. These systems use mainly controlled AC / DC converters and DC / DC converters (intelligent chargers) which are significantly cheaper than DC / AC converters (three-phase or single-phase inverters). The battery bank is charged as part of a centralized DC bus system via the DEG (or GEG), which pollutes the environment, makes noise and does not fit into agricultural systems for the production of "organic food".

Based on the above, the idea in this research is to eliminate the use of DEG (or GEG) and to use the electrical AC grid in the RES hybrid system as a supplementary source and not as the main and dominant (or predominant). Therefore, a modified centralized "DC-bus" topology of the hybrid power system is proposed, which is given in Figure 5.

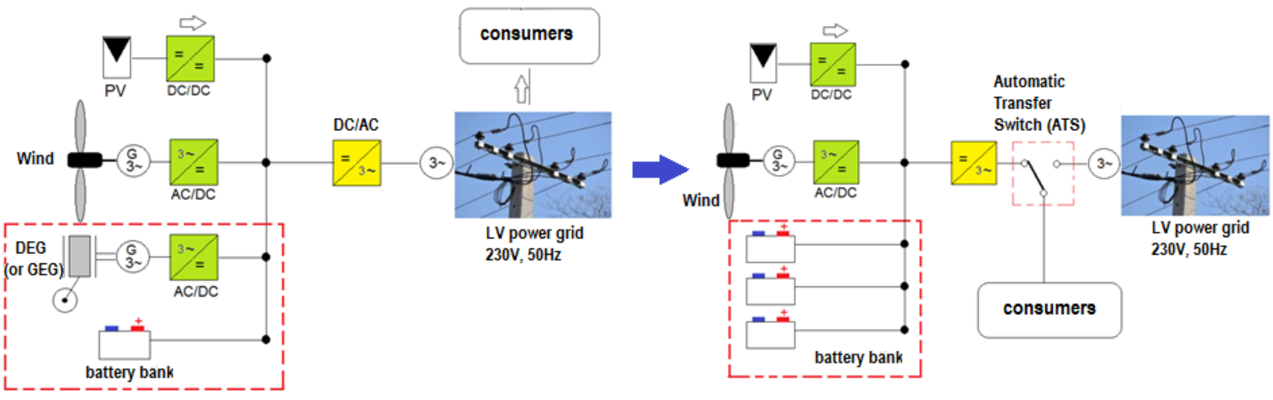

Figure 5. Principle of the modified "DC-bus" topology of a HPSS based on the use of automatic transfer switch (ATS)

In these cases, it is necessary to use an automatic transfer switch (ATS) which ensures fast and reliable switching of the system to the mains supply and vice versa from the mains supply to the RES system. In this way, the mentioned HPSS become uninterrupted. The dominant energy source is RES, while the grid is turned on only when necessary (lack of energy from RES, derating battery capacity or similar).

4. HYBRID POWER SUPPLY OF AGRO KAPILARIS® IRRIGATION SYSTEM

The Figure 6 shows the principal block diagram of the irrigation system, as well as the associated system of HPSS to consumers on the agricultural plot, which is based on the irrigation of vegetable crops according the system "Agro Kapilaris". Specifically in this case, it is an agricultural plot of the Secondary Technical Agricultural-Chemical School from municipality Obrenovac, Serbia on the location of the village Grabovac.

The main power consumers in this system are: (1) hydraulic pump with mechanical power 750W (for the given pump efficiency of 57%, input electrical power is about 1300W), which serves to pump water into the water storage tank, (2) drive of the compressor with power of 100W in the greenhouse (serves for inflating a double foil in order to create thermal insulation and tightening of the foils), (3) drive for raising and lowering the greenhouse blinds, i.e. for controlled ventilation of the greenhouse, with power 2x100W (two drives were realized on each side of the greenhouse).

The pressure pump supplies water to a separate tank located in the greenhouse. Chemical additives are added to the tank through a special dosing system. The water tank contains an inductive indicator with a float that serves to maintain the water level in the tank between the minimum (MIN) and maximum value (MAX). The pump that pushes the pressurized water fills the tank when the level is below the MIN level (then the main switch K1 of the pump drive motor is switched on). When the MAX level is reached, the indicator gives a signal to turn off the main switch K1 of the pump drive motor and the water supply to the tank is interrupted. In the event of a level falling below the MIN value, the pump drive motor is switched on again.

In the following, a more detailed technical description of the concept of the HPSS on the mentioned plot will be given. The block diagram of the realized HPSS is shown in Figure 7.

The system of renewable sources (wind and sun) at this location can at best provide a peak power of about 1600W. The DC voltage of parallel connected solar panels is 18÷36Vdc (nominal value is 24Vdc). The line voltage of the wind generator is 30Vrms and it is converted by an AC/DC converter (rectifier) into a DC voltage of about 42Vdc, which is fed to the input of the maximum power point tracking (MPPT) charger. The maximum battery charging current from this circuit is about 10A.

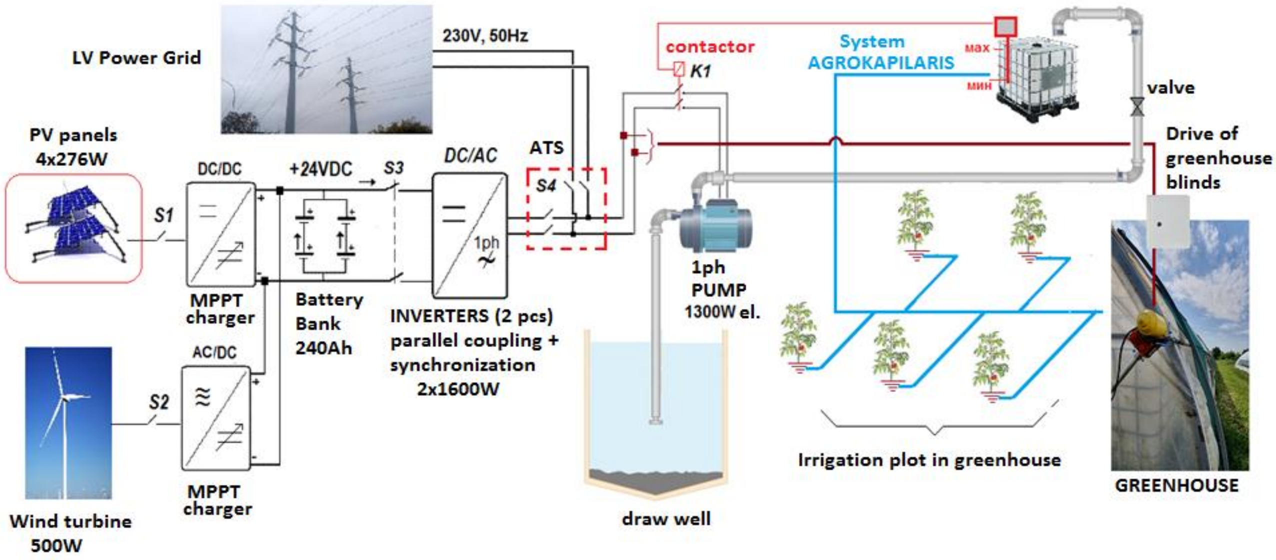

Figure 6. Basic block diagram of the irrigation system and the associated HPSS on the experimental plot "Grabovac"

Stabilization of voltage and current of solar panels in order to charge the battery bank was achieved by a DC/DC converter when the MPPT algorithm was implemented. This electronic module provides controlled battery charging with a maximum current of 20A (at a solar radiation intensity of 1000W/m²). This electronic module has the necessary electrical protection (voltage and current) and provides optimal use of nonlinear current-voltage characteristics and the characteristics of the available power of solar panels. Modules EQ1 and EQ2 for voltage and current equalization on batteries are connected in parallel to each battery group. In this way, even "battery consumption" is achieved and battery life is increased, which is otherwise the most expensive part of the system.

The output single-phase AC voltage of the HPSS is 230V, 50Hz, so that the system has a power converter block consisting of two DC/AC power converters (inverters) connected in parallel and synchronized according to the principle of one main-MASTER, and the other auxiliary SLAVE. These inverters convert DC bank voltage 24Vdc to 230V, 50Hz. This power unit provides power to the consumer in the system as long as there is enough energy from the RES or battery. The inverter block gives a maximum apparent power of 2x1600VA at its output. At a power factor of 0.8, the total active output power is 2400W. This power refers to the most critical case when the ambient temperature is + 40°C. At lower ambient temperatures of + 25°C, the active output power that can be achieved is around 2800W. Since the most critical inverter load is the pump's electric motor (electric power 1300W), an inverter block has been designed that can achieve a maximum output of about 16kW at the start of the pump, in a short time interval of 0.6s, as long as the pump motor starts. Output inverters have implemented voltage protections at the input and output (under voltage and over voltage). In addition to these voltage protections, current protections are provided (overload protection and protection against direct short circuit at the inverter output). The phase current provided by the wind generator is about 6A at a nominal voltage of 30Vrms. Voltage stabilization of the wind generator is provided by an MPPT electronic circuit that is designed for parallel operation with a solar MPPT controller (charger). The three-phase voltage of the wind generator is converted into direct current, via an input rectifier. This rectified DC pulsating voltage is then stabilized and adjusted to the battery voltage. The output current that this circuit can provide is 10A at a maximum wind speed of 10m / s. Therefore, the total battery charging current, taking into account the solar panel charger, is about 30A. This applies to the maximum input power from RES (wind and sun).

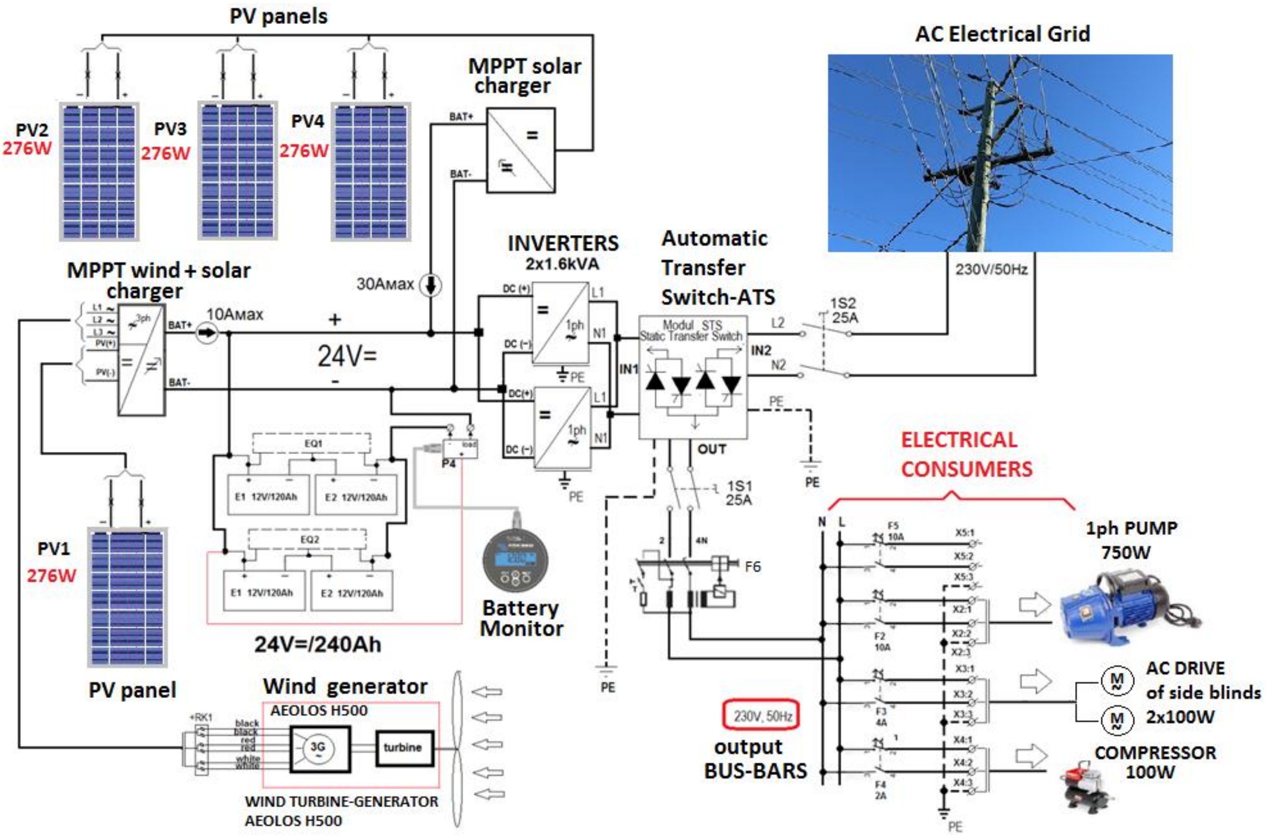

Figure 7. Principle scheme of HPPS on the experimental agricultural plot "Grabovac"

The wind generator MPPT module has the ability to activate the mechanical brake in conditions of strong stormy winds (for wind speeds greater than 10m/s). In this particular case, the mechanical braking of the wind generator assembly is provided at a wind speed of 10 m/s. From the power characteristics of the wind generator [14], it can be seen that at a wind speed of 11m/s (which is a critical case) there is a maximum power of 660W. Operation under these conditions is not recommended, so controlled mechanical braking of the generator is achieved when the wind speed reaches a value close to 10 m/s.

The autonomy of the realized HPSS, for the designed battery bank 24Vdc/240Ah is about 2.5h, at a depth of battery discharge of 50%. For greater depths of discharge (about 80-90%) it is possible to provide electrical energy 4 h. The real requirement regarding the time of autonomy, as part of the application of agro-technical measures of irrigation "Agro Kapilaris" on this agricultural property, is about 2h. In case of battery bank discharge and reduced power from RES (when there is no wind and solar radiation), a system for automatic switching on of the 230V, 50Hz mains power supply has been designed. This is achieved through an automatic transfer switch (ATS) shown in the electrical block diagram in Figure 7. This provides uninterrupted power supply to consumers in the irrigation system (pump drive, greenhouse compressor drive, shutter drive for ventilation of greenhouses and other smaller consumers)

An electronic digital circuit was realized within the battery bank, within which a resistive shunt (measuring resistor) was integrated, for measuring the battery current. Its sensitivity is 1mV / 1A, for the current range 0-500A. Within this module, battery voltage measurement is also integrated, so that the monitoring of the battery bank condition is fully provided (charging current, discharge current, battery voltage, charge status -SOC%, discharge depth-DOD%, remaining autonomy time, etc.). The following values of interest can be monitored on the LCD display of this module: battery charging / discharging current expressed in [A], battery voltage in [V], current available and estimated battery energy up to the final discharge depth [kWh], discharge depth batteries in [%], as well as the state of charge of the battery bank expressed in [%]. Overcurrent protection of the main and auxiliary circuits is performed by automatic circuit breakers, while protection against electric shock on the side 230V, 50Hz, is performed by a two-pole differential protection switch of nominal current 25A. It is marked on the block diagram with F6. The differential protection response current is set to 30mA.

The drive of the side blinds of the greenhouse and the drive of the compressor are supplied from the distribution cabinet which is placed on the internal construction of the greenhouse, at the very entrance of the greenhouse.

The aforementioned equipment and power electronics modules are housed in the main distribution cabinet (MDC). The distribution cabinet is mounted on a metal platform. Dimensions of MDC are 1000x800x400mm. MDC is made of double pickled sheet metal, whose thickness is 2.5mm. MDC is painted and plasticized for the purpose of anti-corrosion protection. This is important, since it is very exposed to external influences (rain, snow, temperature). Therefore, the MDC is provided in the degree of protection IP66.

Considering the “hard” environmental conditions and climatic influences, the MDC is designed so that the equipment in it is in favorable temperature conditions and conditions of relative humidity. For that purpose, forced cooling of MDC is designed, so that a thermostat-hygrostat assembly is placed inside it in combination with a suitable heater and fan (when heating the inside of the cabinet and preventing condensation or when removing excess heat due to dissipation of converter modules). Forced heat dissipation from the inside of the cabinet is provided on the sides of the MDC by means of a fan for extracting hot air. In the summer period, when the ambient temperature is higher than +40°C, MDC ventilation is switched on via a thermostat, and hot air is provided through openings with blinds on the upper side of the MDC. In the winter period when the ambient temperatures are low, in order to prevent condensation in the MDC, a heater of voltage 230V, 50Hz and power 60W is switched on, via a thermostat-hygrostat circuit. In this way, the inside of the MDC is heated in combination with the fan, which dries out the inside of the MDC, thus preventing condensation. On the side of the MDC, there is a junction box with the main switch of the electric drive of the pump, as well as two visual light indications: green - "operation on renewable energy" and red - "operation on the mains supply".

Since there is a voltage of 230V, 50Hz in the system, in addition to the mentioned installations in the HPSS a protective earthing and equipotential bonding installation have been performed. In this way, protection against electric shock is provided, and equalization of potentials in the space where the operator can potentially be found. The installation of a device for differential protection against earth faults provides for additional measures of protection against electric shock.

5. EXPERIMENTAL RESULTS

After the installation of the HPSS, a complete testing and commissioning of the entire system was performed. Below are some of the most important experimental results obtained during in service testing and commissioning.

Figure 8 shows an oscilloscopic records of the battery charging mode via the MPPT solar charger. When these results were obtained (verification was performed in mid-September 2020), the dominant source of renewable energy was the sun, so the given image refers to a solar charger.

Figure 8 (a) shows an oscilloscopic records in the time interval at the beginning of battery charging from the voltage level of 23.5Vdc (at SOC% = 80%) at a constant charging current of about 18A.

Figure 8 (b) shows an oscilloscopic records in the time interval at the end of charging where the battery voltage was about 28Vdc. In this case the battery was fully charged (the state of charge was SOC = 100%). After reaching SOC = 100%, the current from the MPPT charger is reduced to a trickle charge value of 0.1A.

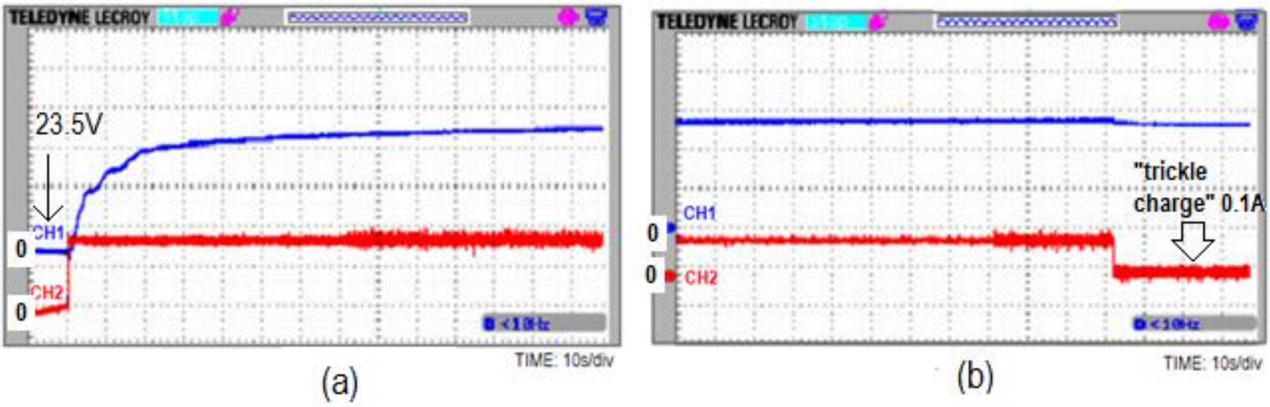

Figure 8. Battery charging mode from MPPT solar charger: (a) time interval at the beginning of charging: battery voltage CH1- [1000mV / div], charging current CH2- [10A / div], (b) time interval at the end of charging: voltage batteries CH1- [10V / div], charging current CH2- [20A / div]

Figure 9 shows oscilloscope records of the current and voltage of the pump's electric motor, during its transition from the inverter supply to the mains supply.

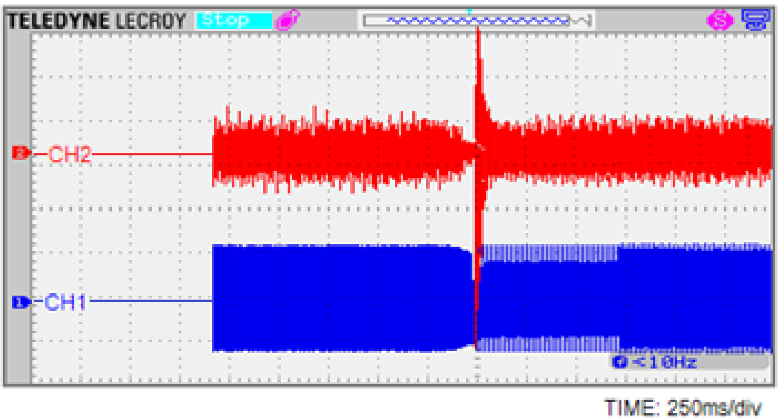

Figure 9. Mode of transition of pump electric motor operation from the inverter power supply to mains power supply; CH1-voltage of electric pump motor [250V/div], CH2-current of pump electric motor [15A/div]

From the oscilloscopic records in Figure 9, it can be seen that in the interval of about 200ms, the power is switched from the inverter to the mains power, via ATS. During this transition a current peak is observed in the pump motor current of about 45A. It is also noticed that during this transition, a certain voltage drop occurs in the interval of about 100ms, which is a consequence of the internal impedance of the inverter output. From the given oscilloscopic records it can also be seen that in normal pump operation, the maximum value of the pump electric motor current was around I_{max} = 7A (which corresponds to the RMS value of the pump electric motor current of In = 5A). The measured RMS value of the current approximately corresponds to the electrical power of the pump electric motor of 1300W.

Figure 10 shows an oscilloscopic records of the starting the pump electric motor in the case when it is powered from the inverter power supply. Within this experiment, a significant reduction in battery voltage (up to 50%) which is a consequence of the starting current of the pump electric motor, which was around 60A. This output current corresponds to the discharge current of the battery bank (24Vdc/240Ah), of about 600A. In this short interval of starting the electric motor of about 100ms, the battery is relatively deeply discharged (up to almost 60%). Expressed in [Ah], this discharge is ΔQ = 600A • 0.1s = 600A • 0.1 / 3600≈0.017Ah. After this, the battery voltage returns to a value of about 25.5V.

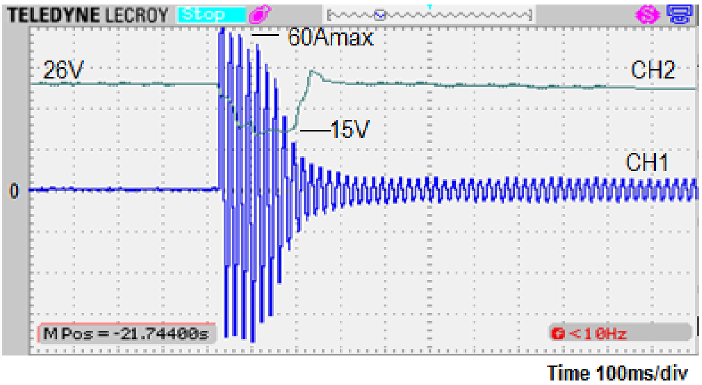

Figure 10. Starting current of the pump electric motor when operate on the inverter power supply; CH1-current of electric pump motor [15A / div], CH2-voltage of battery bank [10V / div]

It should be noted that during the daily operation of the pump no more than 3 to 4 such "difficult starts" occur, so this case is not so critical and the loss of battery capacity is negligible and therefore no additional electronic circuit for "soft start" of the electric motor pumps is needed, because this would further increase the cost of the technical solution.

Figure 11 shows oscilloscopic records of ATS testing during switching from mains to inverter power supply and in the mode of consumes power of about 300W (compressor drives and drive for lifting blinds in the greenhouse were activated).

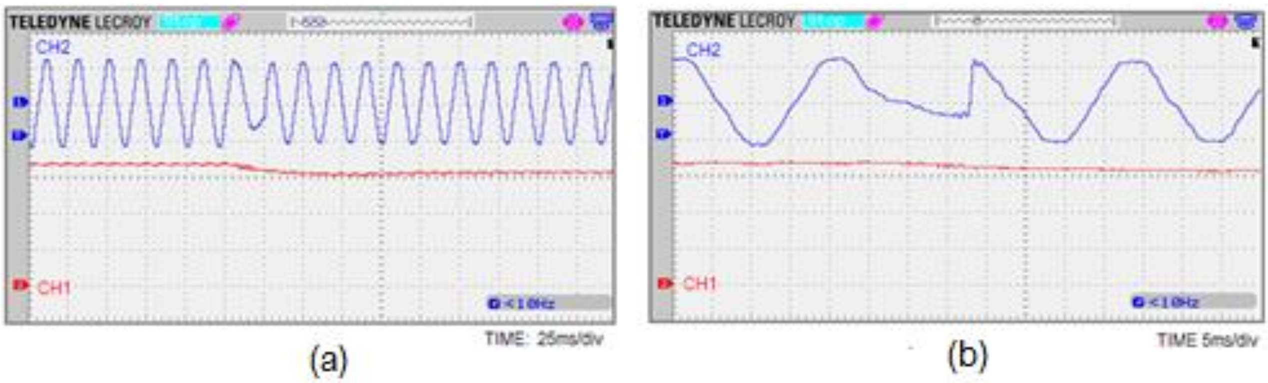

Figure 11. Testing of ATS- switching from mains to inverter power; CH1-battery voltage [8V / div], CH2- consumers voltage (compressor drive and drive for lifting blinds in greenhouse) [250V / div]

Figure 11 (a) shows oscilloscopic records of battery voltage and consumer voltage. It can be seen from the recordings that when switching from mains to the inverter power supply, there is a certain voltage drop on the battery, but that this switching was realized in a relatively short interval. A more detailed presentation of this interval is given in the Figure 11(b) where it is observed that the transition time is about 20ms, which is a satisfactory result.

6. RESULTS OF REALIZATION OF HYBRID POWER SUPPLY SYSTEM

The realization of a HPSS within the pumping and irrigation system on the plot "Grabovac" included ten activities: (1) installation of wind turbine poles, (2) digging of earth channels for accommodation of power and signal cables, (3) laying of power and signal cables at depth of 0.8m, (4) installation of cable PVC shields and warning strips, (5) installation of protective earthing systems: earthing probes 1.5m, earth conductors (or 25x4 Fe-Zn strips), (6) backfilling of cables and earthing systems, (7) installation of MDC, (8) installation of solar panels (9) connection of consumers with MDC, (10) functional testing and commissioning of the entire system.

Figure 12 shows the assembly of MDC and solar panels, as well as the appearance of MDC after foundation. Figure 12(a) shows the appearance of a complete HPSS consisting of a wind turbine on an associated 6m high pole, a solar panel system (3 PV panels on landings on the ground

+ 1 PV panel above the MDC structure) and the MDC itself. Figure 12 (b) shows the installation details of the PV panel system. Figure 12(c) shows the appearance of the installed and funded MDC.

(a) (b) (c)

Figure 13. Installation of MDC and solar panels; (a) the appearance of the HPSS after installation, (b) the appearance of the solar panels, (c) the appearance and foundation of the MDC

Figure 14 shows a detailed view of the MDC, on which the inclined solar panel is mounted, and a view of the interior of the MDC with the associated power electronic equipment. Figure 14 (a) shows the side of the MDC, on which the fan blinds used in the distribution cabinet cooling system are mounted.

(a) (b) (c)

Figure 14. Appearance of the MDC of HPSS with associated equipment; (a) side of the MDC, (b) interior of the MDC, (c) detail of the static circuit-breaker and other protective and switching equipment

Figure 14 (b) shows the interior of the MDC in which the following electrical equipment is located: (1) MPPT wind controller (one DC input for 1 PV panel + three alternating AC inputs from wind generator connection terminals), (2) MPPT solar controller to which three solar panels are connected, which provides voltage stabilization and controlled battery charging current, (3) two DC/AC converters (two inverters), total apparent power 3000VA (active power 2600W), (4) electronic circuit for monitoring battery bank, (5) battery bank 24V = / 240Ah, (6) air conditioning fans of MDC, (7) heaters, 60W for MDC interior heating, (8) ATS assembly and other protective and switching equipment, (9) MDC ventilation drain with blinds.

Figure 15 shows the arrangement of equipment in the greenhouse. Figure 15(a) shows the installation details of the greenhouse rising/lowering blinds system. Two electric motor drives (motor-gearbox group) each with a power of 100W are used to rising/lowering the blinds, which are mounted on the side of the greenhouse. Figure 15(c) shows the innovative Agro Kapilaris® irrigation system in greenhouse and Figure 15(d) shows the detailed appearance of water storage tank with MIN/MAX level indicator.

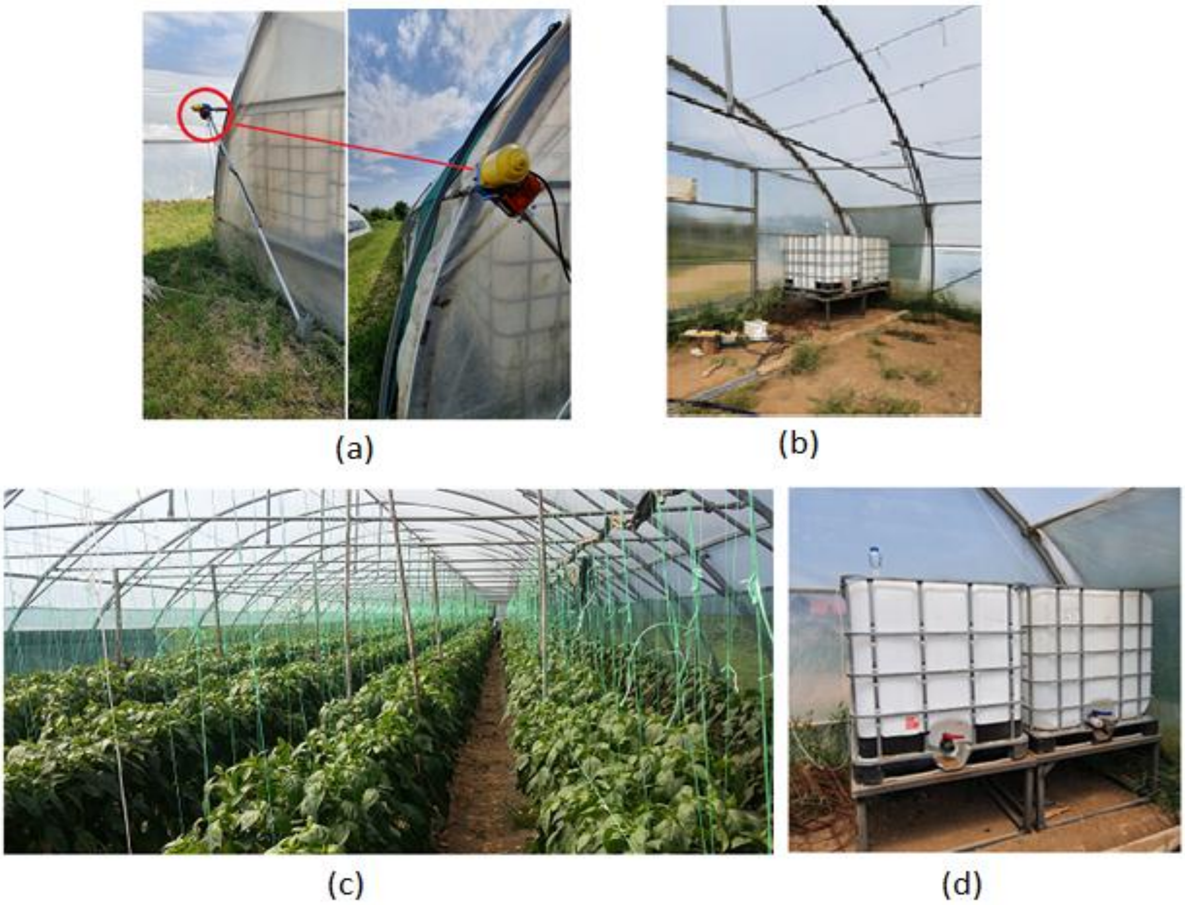

Figure 15. Disposition of equipment in the greenhouse; (a) lifting blinds system, (b) position of water storage tank, (c) Agro Kapilaris® irrigation system, (c) detailed appearance of water storage tank

Based on the information on the water level MIN/MAX in the tank, the electric motor of the pump drive is switched-on or switched-off, i.e. the controlled filling of the water tank is provided. This water tank is actually a water accumulator and is very important in the process of irrigation by the method of "Agro Kapilaris".

CONCLUSIONS

Within the presented paper, the realization of a type of HPSS that provides autonomous and uninterrupted power supply to consumers in the irrigation system "Agro Kapilaris" of vegetable crops, as well as other consumers (compressor drive and mechanisms for greenhouse lifting blinds system) on the experimental plot of Secondary Technical Agricultural-Chemical School from Obrenovac, on the location of village Grabovac. The presented realization of the hybrid power supply system is one of the key results of the realization of the project "Natural resources of wind, sun and water in order to improve agro-technical irrigation measures: application of green technologies in the function of sustainable rural development of Serbia" (topic 9). The project was implemented within the Incentive Program for the improvement of the system of creation and

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