Analysis of Automated Photovoltaic and Lighting Infrastructure Systems

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***Abstract*- The technical solution is based on the implementation of local energy centers - energy points, representing photovoltaic systems of class solar tracker, inverter stations, storage elements (batteries), controller for system configuration or own-developed software platform. The study is development of photovoltaic installations using built or new infrastructure for street, park or area lighting, and this type of installations will exceed the efficiency of the existing lighting systems with solar modules and accumulators. In this paper a new concept of technical solution and components of technical system for highly efficient photovoltaic installations integrated into street and area lighting with two-way transmission of power without use of local electric accumulators is explained.**

Index Terms- Intelligence street lighting control; Photovoltaic in street lighting systems; GIS in street lighting systems.

1. INTRODUCTION

The aim of automated photovoltaic and lighting infrastructure system is for the solution of monitoring and management of the process of the electricity generation. The technical solution is based on the implementation of local energy centers - energy points, representing photovoltaic systems of class solar tracker, inverter stations, storage elements (batteries), controller for systems configuration and own-developed software platform. It includes own made software for control and energy management, which leads to increased reliability and efficiency of the system. The main objective of it is development of photovoltaic installations using built or new infrastructure for street ,park ,or area lighting. .In the case of a preferential purchasing policy for eco-energy, the difference in the cost-benefit ratio between the generated and consumed energy from lighting systems will be more than 7 times. Even in the absence of such a provision, lighting systems will have the effectiveness of the difference between the cost of daily, daily peak and night energy.

2. CONCEPTION

The basic operating principle consists in rendering the expensive generated Eco-energy to the electric power supply system (EPSS) in daylight hours .Thus the infrastructure lighting facilities will be producers of electricity during the day and consumers of electric energy at night.

The outcomes of proposed technical systems are:-

1. Building of photovoltaic installations by using the existing topology and infrastructure equipment for street lighting (poles, low voltage (LV) cable lines
2. Introduction of street lighting control system for remote monitoring and control.
3. High technical-economic effect – the expensive eco-energy generated is rendered to the distribution LV networks during the highly loaded day time.
4. Improvement of energy efficiency of the electricity consumption by using LED lighting fixtures. Possibility of building the system preserving the existing gas-discharge lighting fixtures.

The presented technical solution allows efficient use of photovoltaic installations without injection of generated electricity to the grid. The project is based on the use of energy centers (energy points) located near to the theoretical potential centers of electrical loads. Energy points are Solar tracking photo-voltaic system equipped with specially developed power inverter panels, charging stations, battery components, controllers and software. For achievement of high reliability in winter and optimization of installed power of photovoltaic modules and batteries is used Grid-On scheme. Power injection to network is prohibited by the segment controllers, but the connection and synchronization with grid are needed for recharging of the batteries in days with the longest duration of night time and also in bad meteorological conditions.

3. ANALYSIS OF CURRENT STATE

Photovoltaic installations (PVI) in terms of their application are grouped into three types:

1. PV plants (farms) – installations of considerable power located outside the towns and villages;

PV plants (farms), in general, are far from the populated areas, i.e. the electricity produced by them has to be transformed to medium and / or high voltage, transported over long distances and back transformed to low voltage to meet the needs of consumers. This determines the existence of permanent loss from transmission and twofold transformation of voltage level. In this type of PV systems, it is possible to achieve the best ratio between investments made and energy yields.

2. Urban type PVI – located in roof areas etc., in towns and villages;

The second type of PV systems located on roofs in urban areas do not have the main disadvantage of the PV plants - they are close to the consumers and they have significantly lower losses from transmission and transformation. Their main drawback is that currently the solar modules for DHW (domestic hot water) facilities are many times more efficient than PV modules. From an energy point of view, it is much more appropriate for the space-limited roof space to be used for solar modules for DHW.

3.PVI for street, park and district lighting of battery type

The third type of PVI in the technical solutions of today operates based on the principle of charge and discharge of battery. This type of installations is suitable for use in towns and villages without street lighting infrastructure and/or its erection would be very expensive (for instance, outlying mountain villages, small villages without electricity power supply systems, etc.).

4 .TECHNICAL SOLUTIONS

The topology of the developed system keeps the current state of the existing power lines and poles. The concept of the system is based on the different operating times of photovoltaic installations and lighting systems, allowing the same network cable to be used as street lighting and transferable to photovoltaic modules. Synchronized inverters are placed in street lighting cassettes (distribution boxes) that retain their existing location. Photovoltaic modules are located by two or more on a single pole, and this is determined by mechanical and aesthetic considerations for each object. The aim is to increase the voltage to levels at which grid voltage losses will be allowed.

The use of centralized inverters allows easier control and more reliable synchronization, compared to the use of micro inverters for each pole. To configure the network in different modes, control and protection, specially developed local controllers for each pole are used.

The developed system has three levels:

- Local controllers for each pole;
- Distribution boxes for control of street lighting and photo- voltaic installations;
- Software for street lighting control, energy management and maintenance planning

The developed topology and technical solution allows energy injection and Grid-Tie regime in obtaining authorization and permission to release electricity to the grid.

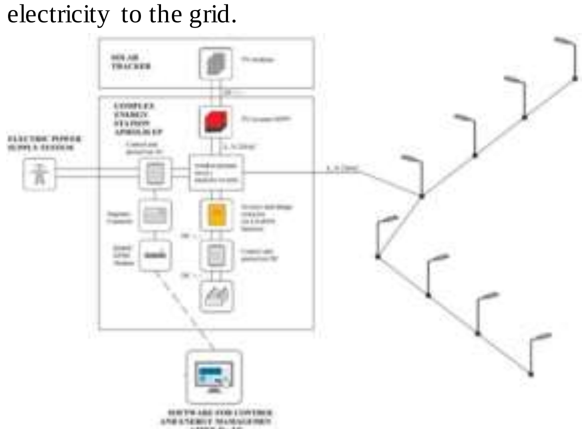

Diagram of automated photovoltaic infrastructure system

The main functions of local controllers are related to control and protection of luminaries, photovoltaic modules and communication with segment controllers.

The main functions of the cassette are control and protection of segments of street lighting system, photovoltaic installations and the operation of the inverters.

The software platform for management and control is own development and provide the following main functionality:

- Geographic Information System (GIS) compatible with Google maps;
- Monitoring the status of the system and equipment;
- Creation and storage of database and reports;
- Windows, Linux and iOS compatible
- Energy management;
- Maintenance management and planning,
- Maintenance management and service planning, including evaluation of the lifetime of the equipment, warranty engagements and database for repair and replacement of components.

The management functions are performed by a own-developed segment controller.

The main functions of segment controllers are:

- Configuration of system scheme;
- Measurement of electricity consumption and energetic parameters;
- Management of the system by integrated load profile and / or external light sensor (photocell);
- Touch-screen interface for system configuration and visualization of energetic parameters
- The normal mode is Grid-On with the option for recharging the batteries and prohibition for injection to the grid.

The design and construction of this type of system requires a reconfiguration of the entire cable network of street lighting. For effective use of the photovoltaic and batteries is necessary to reduce energy consumption and renovate street lighting with energy efficiency luminaries in accordance to the requirements of the standards for light environment. This project propose replacing of all luminaries HPS 50, 70 and 100W with LED 20 and 50W.

Reconfiguration of power networks for street lighting does not affect to the primary cable lines. Power supply of cable segments is changed from transformer substations to the new energy points. Energy points are powered by the closest transformer substations.

5. TECHNO-ECONOMIC ANALYSIS

The techno-economic analysis of the project is prepared in accordance with Technical assignment of the investor and current regulations. The Investor's assignment describes its intention for reducing the cost of electricity for street lighting by replacing existing street luminaries with new LEDs light sources, application of street lighting management system and implementation of renewable energy sources.

The following situations were considered to justify the final technical solution:

Solution 1: Construction of individual lighting units, combined with photovoltaic panels, individual accumulator and charger.

Solution 2: Construction of a new street lighting system including a management system with the building of a separate photovoltaic system for electricity generation within the regulation of the settlement

Solution 3: Combining the lighting system with power generation system consisting of renewable sources, battery station and management system.

- When examining Solution 1, the following conclusions were reached:

Technically it is not possible to install solar street lamps due to infrastructure constraints. The existing pole network consists of steel-concrete pillars placed one-sidedly, on which is installed the electric distribution network of the electrification company for power supplying of the household consumers. In many cases, there is woody vegetation on the opposite side of the street or there is no physically separate pavement.

- This approach contradicts the investor's assignment to introduce a street lighting management system because of the fact, that all newly installed solar street lamps can not physically merge into a connected system, and in the case of a technical solution to that, it would be economically unreasonable due to the high value of the investment for new grid;

- The system will be serviced by technical staff at 270 individual points with additional cost for periodic diagnostics of the system;
- A positive aspect is the possibility for the investor to save 100% of the cost of paying electricity for street lighting, but without guaranteeing the fulfillment of its main purpose - providing quality services to the citizens with minimizing of the costs.

- When examining Solution 2, the following conclusions were reached:
- The possibilities for installing of 22.65 kWp system within the urban area are small. The investor does not have a sufficiently suitable area, including a roof area for deploying a photovoltaic installation with the desired nominal power. The only technical possibility is to build a photovoltaic installation on solar trackers. Possible tracking locations are also technically limited. The preferential prices for the production of electricity from renewable sources do not take into account the specific values of an individual investment project, but the average prices taken from official sources reflecting the international experience as well as the acquired and developed experience in the country.

The prices are determined by calculating the present value of the financial flows obtained through the average of the necessary revenue determined by the Commission in the mentioned pricing elements. Prices are annuity for the period of mandatory purchase of electricity.

Pricing elements are:

- Investment cost;
- Inflation;
- Rate of return on capital and capital structure;
- Average annual work load of plants;
- Size of operating costs.

Taking into account the influence of the individual elements that affect the price level, the working group offers the following preferential prices, on which the public supplier, respectively the end-suppliers, to buy electricity produced from photovoltaic power plants [8] (Table 1):

The following factors are considered in the present case:

- Purchase price;
- Maintenance cost;
- Investment cost;

- When examining Solution 3, the following conclusions were reached:
- There is a technical opportunity for building of photovoltaic installation located on solar tracking system with the required installed power;
- The system will be out of the normative definition for approved usage period of 1342 hours per year, and will be able to use a full cycle of work of about 2000 hours a year;
- The system can be automated and centralized;
- The usage of storage elements - battery equipment with a charge / discharge cycle of at least 6000 cycles, ensures reliability and long service life;
- The expenses for purchasing electricity for street lighting will be reduced to 0 or close to 0;
- The expenses for operation and maintenance will be close to or equal to the normative ones;
- Lack of regulatory restrictions imposed on the investor;
- The main purpose of the investor will be fulfilled - to provide a quality service to the citizens;
- The investor retains the possibility to finance the investment through the obtaining of grants from various programs and donors;

6. FUNCTIONALITY

The hardware and system software provides the following basic features:

1. Flexible management
2. Multi-level lighting control
3. Energy management
4. Reliability and security
5. Modularity

The developed system represents an innovative technical solution for building integrated infrastructure systems for lighting, electricity production by photovoltaic modules and GIS based software systems for monitoring and control. The presented approach achieves the efficient use of photovoltaic modules as a source of energy in street lighting systems, ensuring generation of electric energy and injection to the grid in a daytime with the absence of accumulator's elements. The paper is a modification of the system automated photovoltaic lighting infrastructure system, which ensure efficient operation of photovoltaic systems in street lighting in case of limitation of the generation of electricity in the network provoked by technical or regulatory restrictions.

The software platform is a web-based and includes expanded energy and maintenance management functions for which is not known to have a complete analogue worldwide. The flexibility of the software platform and the web-based concept allow the use of mobile devices or tablets as user terminals on the system.

ACKNOWLEDGMENT

The author is thankful to the supporting faculties for giving facility and opportunity while doing the work.

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