Photovoltaic Systems Integration Rules and Restrictions in the Historic Buildings Architecture

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Abstract. Solar photovoltaic systems integration into historic buildings can change significantly the expenses and energy consumption balance in the most energy-unfavourable urban planning segment. A major challenge of renewable energy sources integration is historic buildings value and aesthetics preservation, subject to present legislation compliance and legacy preservation policies. This publication evaluates the solar photovoltaic systems integration in the scope of finding consistency between legal and aesthetic restrictions.

1. Introduction
The desire of our country to rapidly integrate into the European Community requires decisions to improve the energy performance of buildings, both modern and historical, and increase the share of renewable energy sources. The historical environment is extremely sensitive to any disharmonious influences. The legislation of Ukraine on cultural heritage conservation is mainly aimed at protective (restrictive and prohibitive) rules. The conservation status, by the decision of the Cabinet of Ministers of Ukraine, is granted to architectural monuments when introducing in the register. The overwhelming majority of historic buildings are not monuments, but create a "traditional nature of the environment" and the basis for discovering new monuments are beyond all classifications. This "partial" acceptance of value makes the task of solar photovoltaic systems (SPV system) integration extremely difficult.

The publication investigates the possibility of solar photovoltaic systems integration based on the value degree of historical territories and buildings. The object is to determine the rules and restrictions of the SPV systems integration based on the formed own classification of buildings and territories of the conditional historical area by historical-cultural value.

2. Main Material Presentation
A major challenge is the regulatory uncertainty of the SPV systems integration in the scope of legacy preservation. However, no document prohibits the use of solar photovoltaic systems in the historical environment. With due regard to the heterogeneity and diversity of the nature of historic development, the integration of SPV systems is only possible provided the physical and visual impact is minimized. For situation analysis, a clear and understandable system for determining the possibility and level of intervention for legislative purposes is needed. It is necessary to carry out step-by-step identification and determine the basic requirements, conditions and regulations of the SPV systems integration for each building.
During the research, the legislative and regulatory documents on the protection, preservation and restoration of cultural heritage, also the results published on this issue, and the energy-saving problems of works by domestic and foreign authors were analysed: Vecherskyi V. V., Plamenytska O., Bevz V. M., Vodzynskiy Ye., Karnabid A. A., Konoplova O. V., Lohvyn H. N., Lukianchenko V. I., Mohytych R. I., Kandt A., Khaas F. and others. The analysis of academic papers allows us to draw a conclusion about the absence in Ukraine of legally defined integral classification of territories and buildings of historically formed development by historical and cultural value.

During the USSR period (when the Union was the sole owner of lands and buildings), the protection of cultural heritage buildings was implemented on a territorial basis — through the conservation of historical and cultural lands, definition of protected areas and special regimes of land use. With infinite possibilities, the state could at any time carry out urban, architectural, landscape transformations, relocating residents from any buildings and areas, or changing usage regimes. The value of buildings and areas, among other things, was considered in terms of ideology. We have inherited this conservation system. But when different types of property, a huge number of owners and the creation of new "rules of the game" appear, the situation has changed radically. And in this situation, the "value" of special-use areas becomes greater and needs to be defined more clearly. The territorial principle of the conservation and preservation of monuments continue to be relevant today. The land value is interrelated with its purpose and usage regime. Under the terms of Article 162 of the Land Code of Ukraine, a special usage regime of historical and cultural lands is provided  

Essential features of the legal regime of these lands are directly derived from the designated purpose. Although there is no direct indication of this in the legislation, activities that contradict their designated purpose are prohibited on lands of historical and cultural significance. This principle derives from the general arrangement for the use of land for its designated purpose, as provided by the provisions of Articles 91, 96 of the Land Code of Ukraine [3]. All lands of historical and cultural purpose have a single designated purpose — the location and conservation of heritage sites. The Law of Ukraine "On Regulation of Urban Development" (Article 24, item 2, Paragraph 2) defines that "... development of land is carried out within its designated purpose, established under the law" [4]. The "Land-use classification" [5] defines lands, and their purpose: 08.01 To ensure the protection of heritage sites; 08.02 For accommodation and maintenance of museum institutions; 08.03 For other historical and cultural purposes. Under the provisions of Article 53 of the Land Code of Ukraine, the lands of historical and cultural purpose include lands on which are located: conservation areas; historical and cultural conservation areas; open-air museums; memorial museums-estates; cultural heritage objects, their complexes (ensembles) [3]. Based on the above, we can say that in the absence of reserves, protected areas, open-air museums and memorial museums, the territory of architectural monuments form valuable areas for legislative purposes. The basis for the traditional character protection of the individual monument's environment and complexes is "protected areas": monument protected areas and development control areas.
2.1. Nuances in terminology

It is worth noting several contradictions and inaccurate terminological definitions in legislative and statutory documents. Concerning contradictions: the resolution of the Cabinet of Ministers of Ukraine "On approval of the Procedure for defining the boundaries and usage regimes of historical areas of settlements, restriction of economic activity on the territory of historical areas of settlements" in Paragraph 11 considers protected areas as historical and cultural lands. This is the only document with such a statement [6]. Regarding inaccurate definitions:

1) "Territory of monuments" — the term and its definition are given in 2 different documents in different ways:
   a) "territories of architectural and urban planning monuments are land plots on which monuments are located and connected with land plots historically and functionally, and ensure their preservation and functioning as cultural heritage objects" [7].
   b) "the territory of a cultural heritage monument is a land plot of a monument within its historical and natural boundaries" [8].

Note that these definitions do not correlate in any way with modernity, the change in the ownership paradigm, or changes in land-use boundaries. It must be admitted that not all monuments have defined territory boundaries, and most of them bear no relation to the historical parcel.

2) "Monument protected areas" — the term and its definition are given in three different documents, in similar but different versions:
   a) "monument protected areas (hereinafter — protected areas) are established around the monument protected area, development control area, protected landscape area, a protected area of the archaeological cultural layer, within which there is a special regime of their use" [1].
   b) "cultural heritage object protected areas are established around the monument protected area, development control area, protected landscape area, a protected area of the archaeological cultural layer, within which there is a special regime of their use" [8].
   c) "protected areas architectural and urban planning monuments are areas established around monuments of architecture and urban planning (protected areas, development control area, protected landscape area), and in which there is a special regime of land use" [7].

3) "Monument protected areas" — the term and its definitions are given in two different documents in different ways:
   a) "cultural heritage object protected area is an area adjacent to the area of the monument (including a monument listed in the World Heritage List), which is established under legislation" [9].
   b) "protected areas architectural and urban planning monument is an area adjacent to the area of monuments and aimed at preserving their immediate environment" [7].

4) "Protected area mosaic" — the term and its definition are given in two different documents with similar but different wording:
   a) "protected area mosaic of architectural and urban planning monuments is a combined protected area established for a certain set of monuments in the area with their high concentration, with land bordering or partial combination of monument protected areas to comprehensively preserve the traditional nature of the environment" [7].
   b) "cultural heritage object protected area mosaics are combined protected areas established for a certain set of cultural heritage objects in the area with their high concentration" [9].
5) "Development control area" — the term and its definition are given in two different documents with small but still significant differences:

a) "development control area is a built-up or designated area outside the protected area of cultural heritage objects, which is determined to preserve the dominant role of monuments in the composition and landscape of the settlement" [9].

b) "development control area is a built-up or designated area outside the protected area, which is allocated to preserve the role of monuments in the composition and landscape of the settlement in the formation of the traditional nature of the environment" [7].

6) Significant historic buildings, valuable historic buildings — different terms describing one category of buildings and are given in two different documents:

a) "significant historic buildings — houses and buildings that have artistic and historic significance and are characteristic of a particular historical settlement. They belong to the representative examples of architecture and construction of the period-appropriate and, along with heritage sites, and play a decisive role in the traditional urban environment" [8].

b) "Valuable historic buildings — houses and buildings that have artistic and historical value, are characteristic of a particular historical settlement or belong to the typical examples of architecture and construction of the era and along with architectural monuments play a decisive role in traditional urban environments" [9].

7) "Renovation of historic buildings" — this term has a definition but no application.

a) "Renovation of historic buildings is a restoration of the appearance of obsolete and worn-out buildings and housing (excluding monuments and newly discovered cultural heritage sites) with the modernization of internal planning under modern requirements and modern materials" [9].

8) Regeneration, revaluation, revitalization — these terms are used in the document regarding the Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972, but do not have a legally confirmed definition of these terms in any legislation. Within the context of the document: "Regeneration (in particular, revaluation and, if necessary, revitalization) should be predominant here" [9].

This misreading leads to some chaos and affects the definition of restrictions and possible interventions. Taking into consideration the above, we have preferred the statutory terms given in the documents with a higher legal status.

2.2. The value of territories
There are no special contradictions in assessing the territorial principle for separate monuments and their protected areas. Complex protected areas have another situation. Parts of the territory of such an area (or development control areas) may have different building density of different categories. In such cases, the criticality of the intervention will be different both in terms of formal constraints and in terms of impact on the traditional environment. There is a need to define subcategories that would allow a more precise formulation of requirements, terms and limitations, both for the integration of solar photovoltaic systems and any interventions. Create our conditional classification of territories according to the degree of the historical and cultural value of the building, with the limitations formed by the regimes of protected areas and assign the level of criticality of the environment (context-sensitivity) to the integration of SPV systems for each degree. The separation by characteristic in terms of different options for the density of monuments and their protected areas, large and ribbon buildings and areas of disharmonious development makes it possible to form five degrees of value and assign them the appropriate levels. Determining the level of criticality of the environment (context-
sensitivity) opens the possibility of a system forming for assessing the quality of integration for areas of varying degrees of value (Table 1).

**Table 1. Classification of territories by degree of historical and cultural value**

| Degree of value | Protected areas | Characteristic of historical development | Permitted actions                                                                 | Integration level of criticality (context-sensitivity level) |
|-----------------|-----------------|------------------------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------|
| 1               |                 | Dense location of architectural monuments and significant historic development, a few ribbon buildings, the lack of areas with disharmonious buildings (numerous frequently imposed protected areas). | Restoration and rehabilitation of monuments, protection of the traditional nature of the environment, reproduction of lost valuable objects. New construction is possible only in exceptional circumstances [1]. | High                                                        |
| 2               | protected area mosaic | The distributed location of monuments, the predominance of the significant historic development, ribbon building occupies the rest of the territory, the minimum number of areas with disharmonious buildings (numerous protected areas with small distances between them). | High, above average                                                               |                                                             |
| 3               |                 | Point inclusion of monuments, the predominance of the significant historic development, ribbon building occupies the rest of the territory, the presence of areas with disharmonious buildings (average number of protected areas with significant distances between them). | Average                                                                         |                                                             |
| 4               | development control area | Point inclusion of monuments, dispersed inclusion of significant historic development, ribbon building occupies the rest of the territory, the average number of sites with disharmonious buildings (dispersion placement of protected areas with significant distances between them). | Reconstruction of buildings and housings. The degree of reconstruction is determined by the value of objects, valuable historic layouts and development are preserved, the significance of monuments in the architectural and spatial organization of the historical area is fixed and reproduced; significant opportunity for sightseeing is provided. Reconstruction of existing buildings and housings is regulated by their cultural and urban value and the requirements of preserving the traditional nature of the environment. New developments are regulated by location, methods of organization, height, length of facades, scale, nature of articulations, plastic and colour solutions, functional use [9]. | Average, below average                                    |
| 5               |                 | Monuments absence, point inclusion of significant historic development, ribbon building occupies the rest of the territory, numerous areas with disharmonious developments, (lack of protection zones) | Low                                                                              |                                                             |

2.3. Value of buildings
In the terminological section of SBC B.2.2-3: 2012 "Composition and content of the historical and architectural reference plan of the settlement" [8] there are three definitions that can be attributed to those that form the classification of buildings by value. These are "significant historic buildings", "ribbon historic buildings" and "disharmonious buildings and housings". The last ones are not contextually related to the historic ones and are rather objects that devalue the traditional environment. Besides, new buildings are being built within the historic areas, which are beyond assessment. Adding to these objects the monuments included in the register, we have created our classification, which includes all the buildings located in the historic area (Table 2). Definitions of value categories — conditional and related to existing terms (monuments of world (national, local) significance, significant (ribbon) historic or disharmonious building). By classifying buildings according to the
degree of value, we can determine the degree of impact (intervention) when working with different objects. The listed possible actions concerning the monuments listed in the register are interpreted according to terminological definitions of the Law of Ukraine "On the protection of cultural heritage" [1]. The listed possible actions concerning significant, ribbon, disharmonious and new buildings are interpreted according to provisions of Section 13, SBC B.2.2-12: 2019 "Planning and building of territories" [9]. Values are used as operators to determine the SPV integration possibility: forbidden, partially possible and possible.

Table 2. Classification of historic buildings by degree of historical and cultural value

| Definitions (conditional) | Degree of historical and cultural value |
|---------------------------|----------------------------------------|
|                          | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| Buildings of exceptional historical, cultural and architectural value | Buildings with unique features and high architectural and cultural value | Buildings of special architectural, historical and cultural value | Buildings in which the combination of architectural, historical and cultural features emphasize the tradition of local architecture and the unique features of the building | Historically and architecturally compatible with the traditional architectural environment of buildings without outstanding features | Incompatible (according to terminological definitions of the Law of Ukraine "On the protection of cultural heritage") | New buildings |
| World significance monuments | National significance monuments | Local significance monuments | Significant historic buildings | (ribbon historic buildings) | (disharmonious objects) |
| Conservation, restoration, repair, rehabilitation, museumificatio n, accustomation | Conservation, restoration, repair, rehabilitation, museumificatio n, accustomation | Conservation, restoration, repair, rehabilitation, museumificatio n, accustomation | Conservation, restoration, repair, rehabilitation, museumificatio n, accustomation | Conservation, restoration, repair, rehabilitation, museumificatio n, accustomation | Regeneration, reproduction of lost elements, repair, rehabilitation, reconstruction, repair, rehabilitation, accustomation | Partial or global reconstruction, replacement, demolition. |

Determining the possibility of photovoltaic elements integration

| Possible actions (interventions) | Prohibited | Limitedly possible | Possible | Possible | Possible | Possible |
|---------------------------------|------------|--------------------|---------|---------|---------|---------|

An on-site inspection is one of the components of scientific research in the development of historical and architectural reference plan. It is the visual perception that reveals the appearance features of the monuments, determines the aesthetic value of immovable cultural heritage objects and their role in the environment. Thus, along with the value of the territories and the sensitivity of the context, visual perception and object appearance are one of the main criteria for assessing integration. The possibility of requirements and conditions for the SPV systems integration in/on parts of the outer surface of the building given the permissible interventions according to the above classification is determined. Three main (visible from the outside) elements of the building are considered: roofs, facades, translucent structures (windows and doors), and an additional element — the eaves. Each of the seven categories of value is individual in terms of intervention in the building elements. The possibility and basic requirements and conditions for the SPV systems integration in the construction and elements of the external envelope, depending on the predetermined allowable type of intervention for each category are determined (Table 3). The following values are used to determine the possibility: forbidden, partially possible and possible. The first two columns define the possibility of integration based on the concept of authenticity — all elements of buildings (especially monuments) are authentic. Integration conditions are generated according to possible actions (permitted interventions). The proposed general requirements for appearance are a proposal. It is worth noting the presence in the domestic monument protection legislation of the "monument protection subject" notion, which applies only to monuments. With the introduction of this notion, a certain methodological problem...
arose: the monument is not considered as a holistic structure but as a set of "composite elements", some of which are not subject to legal status. A sufficient condition for the existence of the monument is only its "protection subject" preservation [10]. Therefore, the monument is partially protected, and, except for the "protection subject", is subject to permissible changes. In this study, the "monument protection subject" is introduced solely as a limiting factor.

Table 3. Determining the possibility of SPV systems integration into historic facades

| Degree of value | SPV systems integration into the front and side facades of the building | SPV systems integration into the internal facade of the building | General appearance requirements for the elements of SPV systems (suggestion) | Conditions for SPV systems integration |
|----------------|-------------------------------------------------|-------------------------------------------------------------|---------------------------------------------------------------|----------------------------------------|
| 1              | Prohibited                                       | Prohibited                                                  | -                                                             | -                                      |
| 2              | Prohibited                                       | Prohibited                                                  | -                                                             | -                                      |
| 3              | Prohibited                                       | Limitedly possible                                          | Existing historical finishing materials imitation            | When reproducing the lost elements.   |
|                |                                                  |                                                            |                                                               | Within the reproducible elements.      |
|                |                                                  |                                                            |                                                               | During repairs. Provided that the     |
|                |                                                  |                                                            |                                                               | internal historic facade is not a     |
|                |                                                  |                                                            |                                                               | protection subject.                   |
| 4              | Prohibited                                       | Limitedly possible                                          | Existing historical finishing materials imitation            | At reproduction of the lost elements, |
|                |                                                  |                                                            |                                                               | partial reconstruction. Within        |
|                |                                                  |                                                            |                                                               | reproducible elements and new         |
|                |                                                  |                                                            |                                                               | elements.                             |
| 5              | Limitedly possible                               | Possible                                                   | Existing historical finishing materials imitation            | During repairs. When reproducing      |
|                |                                                  |                                                            |                                                               | lost elements, partial or global      |
|                |                                                  |                                                            |                                                               | reconstruction.                       |
|                |                                                  |                                                            |                                                               | Within reproducible elements and new  |
|                |                                                  |                                                            |                                                               | elements.                             |
| 6              | Possible                                         | Possible                                                   | Formed by the context                                         | In case of partial or global          |
|                |                                                  |                                                            |                                                               | reconstruction.                       |
| 7              | Possible                                         | Possible                                                   | Formed by the context                                         | Contextuality                         |

Table 4. Determining the possibility of SPV systems integration into historic windows and doors

| Degree of value | SPV systems integration into the windows and doors of the front and side facades of a building | SPV systems integration into the windows and doors of the inner facade of a building | General appearance requirements for the elements of SPV systems (suggestion) | Conditions for SPV systems integration |
|----------------|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|----------------------------------------|
| 1              | Prohibited                                                                                   | Prohibited                                                                            | -                                                                            | -                                      |
| 2              | Prohibited                                                                                   | Prohibited                                                                            | -                                                                            | -                                      |
| 3              | Prohibited                                                                                   | Limitedly possible                                                                    | Existing historical glazing materials imitation                          | When re...
It is almost impossible to change or supplement historic facades under the existing legislation. There are regulations for the preservation of historic facades even with the reconstruction of ribbon historic buildings within the historic area. A little more freedom appears on the internal facades, which are not subject to protection in local monuments (in most cases). Of course, there may be exceptions, but when developing a general scheme, the authors tend to consider typical actions. As for the integration of SPV in translucent structures (windows, doors and attics) — the situation is almost the same (Tables 4, 5).

**Table 5. Determining the possibility of SPV systems integration into historic eaves**

| Degree of value | SPV systems integration in existing eaves of the front and side facades of the building | SPV systems integration into existing eaves of the inner facade of the building | General appearance requirements for the elements of SPV systems (suggestion) | Conditions for SPV systems integration |
|----------------|-------------------------------------|--------------------------------------|-----------------------------------|----------------------------------|
| 1              | Prohibited                          | Prohibited                           | -                                 | -                                |
| 2              | Prohibited                          | Prohibited                           | Existing historical glazing materials imitation | During repairs. Provided that the historical glazing is not a protection subject. |
| 3              | Prohibited                          | Limitedly possible                   | Existing historical glazing materials imitation | During repairs and partial reconstruction. Provided that the shape and structures of the eaves are preserved |
| 4              | Prohibited                          | Limitedly possible                   | Existing historical glazing materials imitation | During repairs and reconstruction |
| 5              | Limitedly possible                  | Possible                             | Existing historical glazing materials imitation | During reconstruction |
| 6              | Possible                            | Possible                             | Formed by the context              | Contextuality                   |
| 7              | Possible                            | Possible                             | Formed by the context              | Contextuality                   |

The possibility of integrating SPV systems into/on the roofs of historic buildings is different (Table 6). This is since not all national and local significance monuments' roofs are "protection subject", incomplete legal certainty of possible actions concerning significant and ribbon historic buildings, limited visual inspection. Much of the roofs remain hidden from public space. However, the integration of SPV into the roofs of cultural heritage objects remains in a zone of uncertainty. The problem of preserving the historically composed image of the "fifth facade" is considered both at the urban level (protection of the unique architectural and spatial image of the historic part of the city) and at the level of preservation (restoration) of the historical completion of a particular object [11]. Materials of many pieces of research testify that the formed buildings in historic areas of cities have undergone numerous transformations with a change of architecture and the material of roofs [12]. The number of authentic roofs in the centre of most of the historic cities of Ukraine is small. So, in the future, there will be a need to recreate the lost authentic forms of roofs. This should be taken into account when the SPV systems integration in/on the roof of monuments is carried out.

The conducted research creates a basis for the application of techniques — "masking" (inconspicuous modernization, masking the inclusion of solar energy systems) and "declarative" (location of solar power systems near the monument, on the neighbouring ribbon building). "Demonstratively accentuated" approach (the use of active stylistic and formative techniques with active methods of reconstruction) is contrasting, and requires individual (and rather political) decisions in each case [13].
Table 6. Determining the possibility of SPV systems integration into a historic roof

| Degree of value | SPV systems integration into the existing historic roof of a building | SPV systems integration into/on hidden from public space fragments of a historical roof of a building | General appearance requirements for the elements of SPV systems (suggestion) | Conditions for SPV systems integration |
|----------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|--------------------------------------|
| 1              | Prohibited                                      | Limitedly possible                              | Existing historical finishing materials imitation | During restoration. Provided that the historical roof is not subject to protection, in case of complete roof replacement necessity. Provided that the shape and structures of the roof are preserved |
| 2              | Prohibited                                      | Limitedly possible                              | Existing historical finishing materials imitation | During restoration. Provided that the historical roof is not subject to protection, in case of complete roof replacement necessity. Provided that the shape and structures of the roof are preserved |
| 3              | Prohibited                                      | Limitedly possible                              | Existing historical finishing materials imitation | During repairs. Provided that the historical roof is not subject to protection. Provided that the shape and structures of the roof are preserved |
| 4              | Possible                                        | Possible                                        | Existing historical finishing materials imitation | During repairs and partial reconstruction. Provided that the shape and structures of the roof are preserved. |
| 5              | Possible                                        | Possible                                        | Existing historical finishing materials imitation | During repairs and reconstruction |
| 6              | Possible                                        | Possible                                        | Formed by the context                             | During reconstruction |
| 7              | Possible                                        | Possible                                        | Formed by the context                             | Contextuality |

3. Conclusions
This work brings us closer to understanding the general processes of determining the value and aesthetic limitations of solar photovoltaic systems integration into the architecture of historically formed buildings. In particular, the unclear terminology of legislative and regulatory documents becomes obvious, the contradictions and inaccuracies of which require harmonization. Value characteristics of parts of the complex protected area may vary depending on the value of the buildings located in them. To work successfully with such historical territories, it is necessary to define subcategories by their degree of value. Legislation level defined general classification of buildings by the degree of historical and cultural value is necessary to form general requirements when working with both existing historical and modern buildings. This study suggests that the use of step-by-step assessment schemes can significantly speed up and simplify the procedure for determining the solar power system integration possibility. In the authors’ opinion, the proposed model for classifying historical territories and buildings by the degree of historical and cultural value makes it possible to clearly define the integration of legislative and regulatory restrictions. For further criteria and rules development, it is necessary to determine the most acceptable modern methods for studying the integration of objects appearance from public spaces.

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