RS DETECTION AND PV THEMATIC CARTOGRAPHY FOR ENVIRONMETAL PROTECTION[1]

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Riassunto

Il presente lavoro ha l'obiettivo di progettare e sviluppare analisi nel campo del telerilevamento per la ricerca di soluzioni fotoltaiche tenendo conto delle normative nazionali ed internazionali. Lo scanner MIVIS, avendo 102 canali, è capace di analizzare le firme spettrali di materiali fotovoltaici e di mappare la loro presenza nel territorio. In questo articolo si propone un modello analitico capace di descrivere e monitorare *short* e *long-term performances* di sistemi fotovoltaici. Questo modello implementa modelli di efficienza dei sistemi fotovoltaici con l'individuazione di alcune variabili significative: dimensioni del sistema e costi. I risultati finali di questa attività verranno implementati in un *project-GIS* per la identificazione delle coperture fotovoltaiche nel territorio oggetto di studio. Il progetto potrebbe essere considerato un modello di ricerca per scambi culturali ed implementazioni di Innovativi Programmi Educativi.

Abstract

The present work has been researched in designing and carrying out advanced RS analysis for photovoltaic solutions in compliance with national and international regulations.

The MIVIS scanner, having 102 channels available, is able to define the spectral signature of PV materials and map its presence. In this paper I propose an analytical model able to describe and to monitor short and long-term performances of photovoltaic systems. Such a model shows the efficiency of the system with the more meaningful variables involved in the problem: system size and cost. The final result of this activity is a project-GIS containing the identification of all the roofs that have this material. The project should be considered as an ongoing cultural change: environmental protection means social, entrepreneurial and cultural development. This project will be implemented for Innovative Educational Programmes.

Introduction

The research programme has been researched at designing and carrying out advanced RS analysis and GIS for photovoltaic solutions in compliance with national and international regulations (such as Kyoto Protocol), with the implementation of CDM (Clean Development Mechanism) under

[1] The present research is part of a wide research programme (Official IPSIA Document) for the Minister of Public Instruction (www.ipsia.sabin.ct.it). Part of this research started at the beginning of 2008 and accepted for publication before SIFET 2008. It will be implemented with data fusion analysis, with the support of Landsat, Spot Immages, change detection analysis and other sources for territorial analysis.
The author research will possibly involve the collaboration of the following collegues and specialists: M. La Spina (Head of the IPSIA Giarre), Dott. N. Costa (GeoCos – Nicosia, EN), Prof. Ing. Nicolosi (specialist in the Analysis of Energetic PV Systems - www.ipsia.giarre.ct.it, Prof. Bugiunì (expert in robotics), Prof. S. Bellalba ("Intercultura" Programme www.intercultura.it), to all the IPSIA students, Protezione civile, Arma dei Carabinieri and all the SMEs and Research Centres involved in the project.

certification UNI EN ISO 9001:2000 and 14001:1996 and according to the CE 761/2001 EMAS (Eco-Management and Audit Scheme) standard. Today decision makers who do not have a geospatial information system (GIS) face critical challenges when making decisions pertaining to critical ITC infrastructure. This study could represent an appropriate occasion to disseminate the progresses on the on-going projects belonging to the Sicilian Cooperation Program for Environmental Protection and to exhibit innovative environmentally research in Europe (such as Sicily, Lombardia, Calabria[2] and Friuli Venezia Giulia, Great Britain, Swiss districts[3]), from selected relevant SMEs and companies (certified ISO 9001 and ISO 14001), research bodies, schools and public institutions in order to implement strategies for European Policy. It has remarkably increased developing special expertise to face all those problems related to the production and management of energy obtained from renewable sources and PV technologies (such as mono and multi-crystalline silicon photovoltaic modules) for different purposes and for new applications in survey (Lo Tauro, A. 2008a). The present research can also provide technical support from the design to realization of the PV systems. Photovoltaic (PV) energy generating systems (or PV systems) convert the sun's energy directly into electricity using state-of-the-art semiconductor materials.

PV systems vary in complexity. Some are called "stand-alone" or "off-grid" systems, which mean they are the sole source of power to historical, industrial buildings, private houses or greenway network. Stand-alone systems can be designed to run with or without battery backup. Other PV systems are called "grid-connected" systems. The final cost of any PV system ultimately depends on the PV array size, the battery bank size, and on the other components required for the specific application. This research is planned to generate an estimate for the PV array size and total cost of a standalone PV system in the territory. The thematic cartography will provide an example calculation for exspert using this method. The project will be realised with different technologies (RS, MMS, laser scanning[4], telecommunication, robotics, spatial imaging, VRS and GPS) for the implementation of innovative educational programmes in the field of "Telegeomatics" (Manzoni, G. 2006)

Background

Imaging Spectrometry data or Hyperspectral Imagery mesure the reflectance or emissivity of the Earth's surface in many spectral bands, providing both spatial images and continuous spectral coverage over selected spectral ranges (Goetz et al, 1985). Hyperspectral data acquired using airborne systems have been used in the geologic community since the early 1980's. The solar spectral range, 0.4 to 2.5 micrometers, provides abundant information about many materials (Clark et al., 1990) and new researches could prove the ability of hyperspectral systems to uniquely identify and map different PV materials in the field of Innovation Techologies, even in sub-pixel abundances (Goetz et al., 1985, Clark et.al, 2003, Kruse et. Al. 2003). In fact, research has showen that imaging spectrometry principles and mapping capabilities are extensible to many other disciplines including environmental protection and photovoltaics. In general, one of the limiting factors in many of these studies is the absence of adequate spectral libraries and implementations of baseline studies of the spectral /spatial variability of specific PV materials of interest. For this reason this study is designed as an initial investigation spectral characterization and mapping of PV materials in order to evaluate sizes, long and short term performances and costs of photovoltaic

[2] Thanks To SIT Staff, Regione Lombardia, "Ufficio Territoriale per la Biodiversità" (Cosenza) and "Corpo Forestale dello Stato".
[3] Comet and Erasmus Programme (1992-1996). Thanks to Emanuele Traversari, Custumer Support Engineer (Erdas, The Earth to Business Company) for providing RS data.
[4] "Corso di aggiornamento SIFET 2005" - Topic: "Tecniche Innovative di rilievo e rappresentazione dei Beni Culturali", tutor Full Prof. Benedetto Villa.

systems. We are at the beginning of new Earth Observation age comprised of large amounts of data, high revisit times as well as high resolution images (Dussi, M. 2008).

Furthermore EarthCARE, ESA's Cloud and Aerosol mission developed in co-operation with JAXA, the Japanese Aerospace Exploration Agency, will address the need for a better understanding of the interactions between cloud, radiative and aerosol processes that play a role in climate regulation. The EarthCARE mission aims to improve the representation and understanding of the Earth's radiative balance in climate and numerical weather forecast models by acquiring vertical profiles of clouds and aerosols, as well as the radiances at the top of the atmosphere. The implementation of analytical models will be able to describe and to monitor short and long-term performances of photovoltaic systems according to metereologic variables under RS analysis[5].

Hiperspectral analysis and the Project-GIS

The study aims at defining the relationships between short and long-term performances of photovoltaic systems, system sizes, types, efficiency of the system and highlighting the main morphological characteristics within examined industrial, historical buildings and private houses. These were the results of the application and research of a new classification method (Lo Tauro, A. 2008b) to different bands of the airborne MIVIS data collected within an extensive survey campaign over Catania Province and the Etna Park. This is still a work in progress project. The integration of classification (i.e. segmentation followed by classification) applied to MIVIS multispectral data permitted the identification of PV technologies with a very cost-effective and accurate procedure.

New instrument for PV management utilizing remote sensing helps me to analise important factors such as size, site, selection, shading, and orientation in order to meet high performance data acquisition and distribution service requirements.

Another important aspect involves significant band selection of the Mivis image for thematic carthography. In this particular case I analysed bands in visible and thermal infrared area. The final product of this experimentation was a thematic map expressing the possibility to determine the areas with the highest potential lost of heat in roofs. This analysis can be extended to plannning strategies for PV facades installations with the support of 3D carthography and DTM. The method also described the solar absorbment and the thermal increments of PV surfaces connected to territorial sources (rivers, canals, lakes, etc.). To get over the spectral ambiguity and the spatial complexity typical of such surfaces, a method has been conceived which allows firstly to extract elements and materials present in the study area by means of implementation of classification techniques. The potentialities of thermal data in the discrimination of PV materials have been analised by means of irradiation of surfaces visualizing the temperature at the roofs of industrial historical buildings and private houses. Temperature values detected from images have been integrated with detailed analysis of PV technologies.

The analysis was supported by photo-interpretation of peculiar MIVIS band combinations and by data acquired during field surveys and from a pre-existing CTR maps. The morphologic data were also obtained by processing a raster DTM created from topographic maps[6].

[5] The satellite will weigh about 1.7 tonnes and will be placed in a quasi-polar orbit of 97°deg inclination at an altitude of about 400 kilometres. Its launch is scheduled for 2013. The four instruments of the payload consist of an Atmospheric Lidar, a Broad-Band Radiometer and a Multi-Spectral Imager developed by ESA, and a Cloud Profiling Radar developed by JAXA This instrument suite has been optimised to provide co-located samples of the state of the atmosphere along the satellite flight track (www.esa.int). The research will also involve the analysis of the Goce Programme (www.esa.int.goce)

[6] Lo Tauro, A. et alt (2005)

The projectGIS takes into due consideration the technical output given by Building and Infrastructures Integrated Photo Voltaic Geographic Information System (B.I.I.P.V-G.I.S.) and similar methodologies for Sustainable Development and Environmental Protection[7].
The idea of a real time project-GIS (Manzoni, 2001) can be exstended to the analysis of PV planning with the support of innovative survey. The aim of this preliminary study is to access the potentialities of remotely sensed MIVIS data to plan, locate and analyse PV materials for the construction of roofs and covers of buildings. It is now important to create thematic cartography with the support of RS analysis showing where there are covers built up with PV materials and where they should be installed to be able to plan and monitor them. In fact, the MIVIS scanner, having 102 channels available, is able to define the spectral signature of many materials, including PV materials, and to map their presence. For this reason tests sites have been selected to prove this possibility and an application in the Catania Province has been done. In this project I analysed MIVIS data of the CGP that have planned a flight for the INGV in Rome[8] at the altitude of 2500 meters (pixel size 5 metres). To overcome the spectral ambiguity and the spatial complexity typical of PV surfaces, a method has been analysed which allows firstly to extract recognised elements and materials present in the study area by means of classification techniques. Secondly the potentiality of thermal data in the discrimination of materials have been studied by means of the irradiation of the surface. I also tested the Dower-Spectroscopy-Lab library (http://speclab.cr.usgs.gov) in order to detect and implement analysis of PV materials (such as silicon photovoltaic material and silicon crystals) and in order to do direct PV material mapping and thematic carthography. It was also possible to test the classification of the different typologies of PV technologies comparing those different spectral characteristics of the PV roof with the spectral characteristics analysed by the Dower-Spectroscopy-Lab.

Georeference tests and accuracy measures
An important step in the analysis of PV mapping is the geometric correction of the MIVIS image.
As known, hyperspectral data requires geometric corrections. The nature of typical MIVIS images are connected to the movement of the aircraft and the sensor characteristics (geometric distortions within FOV limits). While I preferred to work with the non-geocorrected data for my spectral analysis, the non geocorrected data and the information to perform basic geocorrection were delivered towards the end of the research, thus only limited studies were performed using the non-geocorrected data. I did use them for the orthorectification studies. In a second phase the geo-referencing process involved a measure of GCP distortion as it computed the square root of the squared deviations to represent a measure of which GCP exhibit the greatest error while the model order determines the order of polynomial used to perform the registration warping. In general, the higher the order of polynomial transformation is, the greater the number of GCPs required for registration and the more complex the warping that can be achieved. Later, after executing all spectral analysis, the images were georeferenced to the National Map System (Gauss-Boaga). Following registration, all of the images were clipped to the boundary of the combined area in Catania Province. Atmospheric correction is also a requirement for this data analysis approach. For this purpose I studied the Atmospheric Correction Now (ARCON)[9] model based on atmospheric correction method for the implementation of didactic activities. The project also involves the analysis of cartographic accuracy. This update of an article first published (Manzoni, G. 2001) explains how methods for real time GIS can create different position accuracy measures and

[7] For more information see Center for Renewable Energy and Sustainable Technology (CREST) www.solstice.crest.org; http://iamest.jrc.it/pvgis/pv/index.htm; http//pvsat.com
[8] Thanks to INGV (Centre for Research on Remote Sensing at Rome) and in particular to Fabrizia Buongiorno for providing MIVIS data. Thanks to Dott. Commini, CNR (Istituto Inquinamento Atmosferico) LARA Programme, P.O.N. "Sicurezza per lo Sviluppo del Mezzogiorno d'Italia", Ministero dell'Interno (CD-ROM).
[9] ARCON is a commercially-available, enhanced atmosferic model-based softwares that uses licensed MODTRAN4 technology to produce high quality surface reflectance without ground measurements (Kruse, 2004).

precision in cartography. Since then the GPS universe has changed significantly and several other factors have also changed. In the last century the dominant applications of GPS were for the military and surveyors. Today, even though GPS numbers are up in different sectors, they are dwarfed by the abundance of cell-phones with GPS; and the wireless industry has its own favorite accuracy metrics. Selective Availability was active in 1998, now it is no longer in use. And finally we have the prospect of a 60+ satellite constellation, as we fully expect in the next nine years that 30 Galileo satellites will join the GPS and satellite-based augmentation systems (SBAS) satellites already in orbit. The research also investigate methods for the georeferencing of PV technologies and in particular "stand alone PV[10]" in the Etna Park with the support of Virtual Reference Station (Lo Tauro, A, 2007). Since atmospheric uncertainties put a limit on the distance whereby on-the-fly ambiguity resolution would still operate successfully, Real Time Kinematic (RTK) applications may require relatively short distances to a GPS reference station. This distance constraint can be relaxed, when use is made of the VRS concept.

Didactic approaches

The use and the diffusion of the RS analysis for photovoltaic solutions database cannot neglect the didactic approach. This instrument is still not used by Public Institutions and it unlikely applies to didactic activities. Furthermore, the principal problem of the use of RS analysis for photovoltaic solutions is related to the cost of the GIS. In order to solve this problem, the project provides methodologies for the elaboration of thematic cartography using open source and free softwares (FOSS) for Geographical Information System (GIS) and Remote Sensing (RS).

Figure 1: An exapmle of PV Map analysis

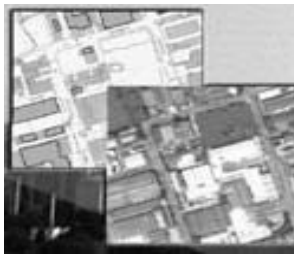

Figure 2: This shows the planning of PV modules

Figure 3: Photograms of the "stand alone system" for the greenway network

[10] Stand-alone PV systems are often best in places where utility-generated power is either *unavailable* (because the area is so remote from power plants), *undesirable* (because of a possible utility power outage in an emergency), or *too costly* to hook up to (because of the price of extending power lines). Stand-alone systems are also excellent for uses that don't require a lot of power.

The didactic activities for high schools, courses for professionists, PMI and post graduate courses (such as International Master Courses) are planned to be structured in different phases: the analysis of the project GIS, the analysis of PV technologies with RS analysis and the case-study with the support of internet serch. The e.learning technologies for didactic activities will guarantee to all researchers, exsperts, professors and students the accuarte dissemination of information with internet and intranet systems without missing data. Distance Education Programmes are especially interested in applicants with the expertise to teach undergraduate and graduate classes online using proprietary Web-based educational delivery software (such as the WebTycho and INDIRE[11]). This project also marks a milestone in the effort to promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedom of persons with disabilities, and to promote respect for their inherent dignity (ONU Convention and National Law - NL 5/2/1992, n. 104, NL 28/1/1999, n. 17, NL 21/5/1998, n. 162, NL 12/3/1999, n. 68, DL 10/11/1993, n. 276, Stanca Law, n. 4 9/1/2004, L 6/9/2004).

Some conclusions

The demand for photovoltaic systems has remained continually high. In European countries such as Spain or Italy, advantageous regulations will lead to a rise in demand, resulting in the overall European demand that remains on a high level. An important step in an economic feasibility study is to compare estimated costs of the PV system to RS analysis and GIS costs. It is important to analyse different factors such as size, site, selection, shading, and orientation. With some careful planning with the support of RS analysis, it is possible to reduce a building's electrical loads by 50 to 80 percent without sacrificing comfort and convenience. The result of this study analyses the utility of airborne remote sensing for identifying PV roofs and discriminating those on which checking for maintenance work. Additional objectives of this research will validate and refine hyperspectral mapping capabilities through a collection of site-specific spectral library. The measurement of additional spectra of key materials, utilising a spectrometer, allow establishment of prototype spectral libraries for potential use in PV technologies. In fact, the additional goals of this research will establish spectral libraries and databases of common PV materials for future use in hyperspectral mapping of PV roof with the support of GIS technologies. Spectra will be compiled into RS compatible libraries and prospective database elements will be identified. Furthermore I will analyse the reliability of my model and the limits of its usefulness under European Programmes including innovative proximal sensing and *in situ* analysis. This includes improved generation of orthorectified map-size products for use in field verification. In Particular "Satellite Positioning (GPS) integrated with INS (Inertial Positioning System), EGNOS (the European system) and later on with GALILEO represent the innovative elements to be used in the collection of such data" (Manzoni, G. 2006). MMS, laser scanning, telecommunication technologies, Virtual Reference Station[12] and robotics[13] implement new methodologies for accurate geographic position and georeferencing of photographic data for PV analysis, innovative PV photographic databases and 3D modelling. In educational programme I also describe laser scanner located on the top of moving vehicles in order to plan and survey PV surfaces and facades with regard to conditions and environment where they are situated related to the risk phenomena in the Etna Park. The objective is to predict, and thus to decide in advance, which measures have to be taken most urgently, with regard to the time necessary for execution in building sites and greenways networks for Civil Protection activities with the support of "stand alone" PV systems. For this reason, hazard maps are combined with PV data (such as the "stand alone" system) about the strength of existing buildings

[11] INDIRE Programme, Minister of Public Instruction, http://www.indire.it/ Lo Tauro, A (2001) – Indire Final Report – Minister of Public Instruction - Didactic Units, Methodologies and Evaluations

[12] Thanks to C.G.T. S.r.L. www.cgtsrl.it

[13] Thanks to "Arma dei Carabinieri"

and the greenways network. I will also focus on the analysis of atmosphere, biosphere, hydrosphere, cryosphere, with the overall emphasis on learning more about the interactions between these components under RS analysis and the impact that PV technologies are having on environmental protection. The project could involve important educational training program which includes students, technicians and researchers in the R&D in photovoltaics and Remote Sensing, under cooperation programs with the main Italian universities, important European and international institutions. Therefore, the encouraging results may encourage public institutions and private companies to adopt these procedures, applied to airborne remote sensing data and real time GIS, to rapidly control and monitoring PV technologies and to exstimate their costs. The tematic carthography is useful for environmental distributed model for the implementation of "Piani Paesaggistici" in order to support decisions in matter of management of cultural and environmental heritage. The present research will be extended to other renewable sources (such as hydropower, wind, geothermal and biomass) and to the analysis of biomaterials in environmental and cultural heritage analysis.

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