PV Hybrid Systems within Mini Grids – IEA PVPS Task 11

Konrad Mauch
KM Technical Services
Vancouver, BC, CANADA
Konrad.mauch@ieee.org

Josef Ayoub
NRCan/CANMET Energy
Technology Centre
Varennes, Quebec, CANADA

Philippe Jacquin
PHK Consultants
Ecully, FRANCE

ABSTRACT

In October 2005, the International Energy Agency Photovoltaic Power System Executive Committee approved a new Task 11: "*PV Hybrid Systems within Mini-grids*" for the period 2006-2011. This new Task builds on the work on PV hybrid systems undertaken in Task 3 from 1994 to 2004.

A particular focus of the new Task is the operation of PV within mini-grids (defined as the interconnection of small, modular generation sources to ac distribution systems). These mini-grids may be powered by a combination of PV, wind, micro-hydro, fossil fuel gensets, and other sources, they typically supply multiple users, and they may be interconnected with (or be part of) the distribution grid of the local electric utility. This raises issues of system control and coordination, sustainability and the role of local electric utilities in different jurisdictions.

This paper presents the goals and objectives of Task 11 and discusses the work plan and approach that will be used to achieve the objectives.

1 Overview and Background

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization of Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its twenty four member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems (PVPS) Implementing Agreement is one of the collaborative research and development agreements established within the IEA, and since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic power systems. In particular, Task 3, which ran from 1994 to 2004, focused on use of photovoltaic power systems, including hybrid systems, in stand-alone and island applications.

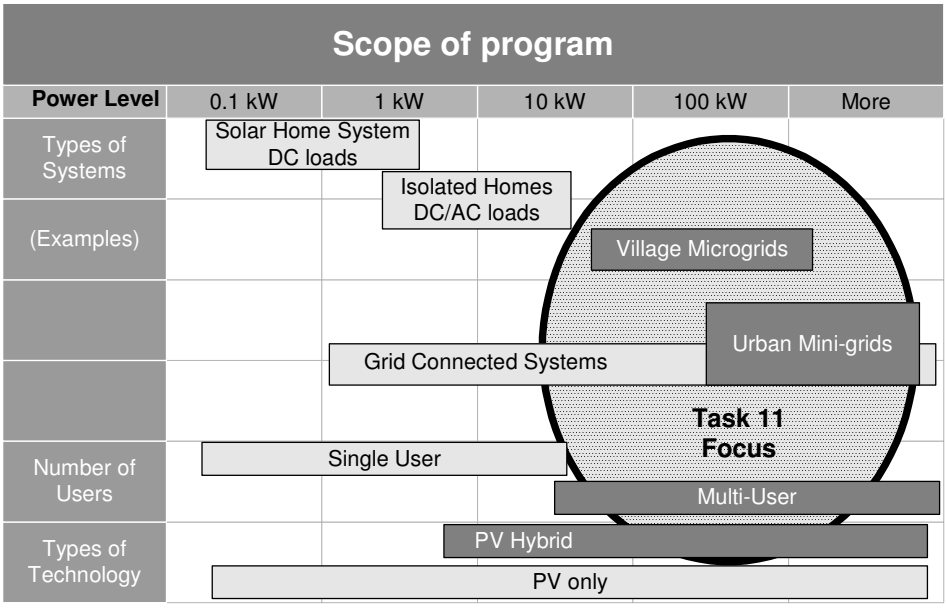
Considerable advances in PV hybrid systems have been made during the course of Task 3. The use of embedded microcomputer controls and other modern electronics have improved component and sub-systems characteristics. Improved energy management, battery management, and dispatch algorithms have been developed and have been demonstrated in installed systems. The efficiency of maintenance has been increased using standard diagnostics and high level human-machine interfaces.

However there remains both a need and an opportunity for international R&D collaboration to further develop PV hybrid technology and to collate and disseminate international knowledge of hybrid systems. In particular there is the need to develop technology and application knowledge for larger hybrid systems consisting of multiple different energy sources interconnected by a local electrical distribution network – the mini-grid concept.

The IEA Executive Committee recognized the need for a new programme to focus on this area and encouraged the definition of a new IEA PVPS Task. Definition workshops for this new Task 11 on PV Hybrids in Mini-Grids were held in Cuernavaca, Mexico in 2004 and in Kassel, Germany in 2005. The Kassel meeting resulted in a draft Work Plan for Task 11 that was approved by the IEA PVPS Executive Committee in October 2005. Task 11 is now officially underway and has had its first Experts meeting just in advance of the 3rd European PV Hybrid and Mini-Grid Conference in Aix en Provence in May, 2006.

2 Scope and Objectives

The scope of Task 11 is PV based hybrid generators that combine PV with other electricity generators and also energy storage systems. A particular focus will be on mini-grid systems in which energy generators, storage systems and loads are interconnected by a "stand-alone" AC distribution network with relative small rated power and limited geographical area. The mini-grid concept has potential applications that range from village electrification in less developed areas to "power parks" that offer ultra-reliable, high quality electrical power to high tech industrial customers. These systems can be complex, combining multiple energy sources, multiple electricity consumers, and operation in both island (stand-alone) and utility grid connected modes.



The main *goal* of Task 11 is to promote PV technology as a technically relevant and competitive energy source in mini-grids. It aims to enhance the knowledge-base of PV hybrid mini-grids and reduce barriers to market penetration of these systems.

The *objectives* of this new Task are to:

i) define concepts for sustainable PV hybrid mini-grids taking into account local factors (specificity of the application, financing regimes, location, others);
ii) provide recommendations on individual designs (mix of technologies, architecture, size, performances, other) in order to achieve high penetration of PV as a mean to improve the quality, reliability and economics of electrification systems such as mini-grids;
iii) assess the potential of technologies to be mixed with PV for hybridisation; and,
iv) compile and disseminate best-practices on PV hybrid power systems.

3 Approach and Work Plan

Task 11 activities will address both technical and non-technical issues that affect the market penetration and uptake of PV hybrid systems. Technical issues include

- design methodologies for PV hybrid mini-grid systems,
- control, communication and interconnection of mini-grids, and
- increasing the energy contribution of PV versus fossil fuel generators within hybrid systems.

These will form the bulk of the work in Task 11. Non-technical issues pertain to the social, economic and environmental conditions through which these systems become sustainable. The work program is organized into the following main subtasks:

1. Subtask 10: Design Issues
2. Subtask 20: Control Issues
3. Subtask 30: PV Penetration in Mini-Grids
4. Subtask 40: Sustainability Conditions

Subtask 10 addresses the complex nature of PV hybrid system design. Tradeoffs have to be made between first cost, energy efficiency, and reliability. Oversizing a system may increase reliability but also increase first cost. Undersizing a system will decrease reliability and frustrate users. The correct choice of components and system architecture is critical. The task has the following three activities

- Review, analysis and documentation of current hybrid mini-grid system architectures
- Evaluation and comparison of system design methodologies and tools and development of guidelines for design tools
- Development of best practices for design, operation, and maintenance of PV hybrid projects

Its primary deliverable will be a "*PV hybrid for mini-grid design manual* " that will meet the needs of system engineers, researchers, and manufacturers in the private and public sectors.

Subtask 20 addresses the need for new coordinating control mechanisms in hybrid mini-grids to maintain grid stability and to optimize the contribution of all generation sources. It has the following five activities

- Investigate existing methods for stabilizing voltage and frequency in mini-grids and develop new, improved methods if required
- Investigate data communication architectures and protocols for mini-grids
- Develop supervisory control parameters and strategies for mini-grids
- Evaluate the role of energy storage technologies to stabilize mini-grid operation
- Investigate technical issues associated with autonomous and interconnected operation of mini-grids and a main utility grid.

The primary deliverable of subtask 20 will be a series of technical reports outlining the results of the activities and providing recommendations for current implementation and for further research and development.

Subtask 30 addresses the goal of increasing the use of the PV resource in PV hybrid systems and displacing fossil fuel resources. It has the following two activities

- Develop performance assessment criteria for PV hybrid systems that allows for objective comparison of different systems
- Develop recommendations to maximize the solar fraction in hybrid systems through demand side management, dispatch strategies and optimization of the battery energy storage system.

The primary deliverables of subtask 30 will be two reports, one describing the performance assessment criteria for PV hybrid systems and the other providing recommendations on strategies to maximize the use of PV (and other renewable energy sources) in hybrid energy systems.

Subtask 40 addresses the social, political, economic, and environmental factors necessary for successful implementation of PV hybrid power systems within mini-grids. It has the following three activities

- Develop case studies that demonstrate the social and political framework for successful operation of PV hybrid systems within mini-grids
- Evaluate the financial aspects of PV hybrid power systems, considering both first costs and operating costs, and determine the conditions for economic sustainability
- Evaluate the environmental impacts and benefits of PV hybrid systems with focus on greenhouse gas emission mitigation and potential for recycling of system components

The primary deliverables of subtask 40 will be three reports discussing the social/political, financial, and environmental criteria for successful PV hybrid systems.

Activities within Task 11 will be carried out on a task-sharing basis among participating countries as in other tasks of the PVPS Implementing Agreement. The Task 11 organizational structure is similar to other IEA PVPS tasks. An Operating Agent is responsible for overall coordination among subtasks and for coordination and communication with other IEA PVPS Tasks and the IEA PVPS Executive Committee. Each subtask has a leader who is responsible for coordination, scheduling and communication between activities. Activity leaders are responsible for planning, scheduling and coordinating the activities and for the production of the deliverable items.

The work plan calls for 170 person-months of work to complete the activities. The participating countries, which currently include Austria, Australia, Canada, France, Germany, Japan, Norway, Spain, and Switzerland, are seeking a multi-disciplinary group of experts with a sound background on photovoltaics and its applications. People familiar with distribution of energy in terms of planning and implementation will be key to this task as well as those involved in the development of new distribution topologies. The group will also benefit greatly from experts in the field of energy conversion technology, whether they to come from the research, manufacturing, installation or standardization sectors. Finally, PV experts with considerable field experience, especially in community energy service providers (planning, supply, installation, maintenance, etc.) are required to address the issues surrounding system sustainability in this Task. Experts from participating countries who are interested in participation in Task 11 are encouraged to contact the Task 11 Operating Agent, Mr. Konrad Mauch, via e-mail (konrad.mauch@ieee.org).

4 2006 goals and next steps

Task 11 began in early 2006. The participating countries are preparing their national participation plans in which they will commit to participation in selected activities. Subtask and activity leaders will be designated and detailed planning of activities will begin. The preliminary work plan for Task 11 calls for several of the activities to produce a first draft of a deliverable item within 12 months, so planning must be complete and work on activities well underway by the end of 2006.

5 Acknowledgements

The Authors would like to acknowledge the IEA PVPS Executive Committee for guidance, direction, and support in developing Task 11. They also wish to acknowledge the participants in the two workshops that defined the scope of Task 11. The participants at the Kassel workshop in September 2005, who contributed to the development of the Task work plan described herein deserve special thanks.