STAND-ALONE PHOTOVOLTAIC SYSTEMS FOR TELECOMMUNICATION STATIONS IN GREECE

M Soursos
SENERS Ltd., 16, Kleovoulou Str., 117 44, Athens, Greece
Tel: +30 1 9270940, FAX: +30 1 9270857

C Protogeropoulos
CRES, Centre for Renewable Energy Sources
19th km Marathonos Av., 190 09 Pikermi, Athens, Greece
Tel: +30 1 6039900, FAX: +30 1 6039905, e-mail: cprotog@cresdb.cress.ariadne-t.gr

P Suuronen
NESTE Oy, NAPS International, Sahkotie 8, FIN-01510 Vantaa, Finland
Tel.: +358 204 505758, FAX: +358 204 505744

ABSTRACT: This paper reports on the design and installation of autonomous solar-powered telecommunications in Greece. Due to the morphology of the mainland in Greece, stand-alone only systems can be installed in particular sites in order to cover satisfactorily the Hellenic Telecommunication network. The photovoltaic systems described in this paper belong to the Hellenic Telecommunications Organisation (OTE). The system design, installation and commissioning have been done by SENERS Ltd. in collaboration with NESTE Oy.
Keywords: Telecommunications - 1: Stand-alone PV Systems - 2: Implementation - 3

1. INTRODUCTION

Telecommunications is one of the fields that has been greatly benefited from the introduction of solar-power systems. With the reduced power consumption of modern telecommunication equipment, solar electricity has become an economically and technically attractive alternative to conventional energy sources. In Greece, due to the morphology of the country, rural telecommunication systems often have to be installed in remote and uninhabited areas. In such regions, it is quit common that no infrastructure exists and therefore, solar systems are the most suitable energy source.

2. DESIGN FEATURES OF A SOLAR PV SYSTEM FOR TELECOMMUNICATION STATIONS

2.1 General

The design and installation of solar power systems for telecommunication projects is a specialist task. As a professional system is not just connecting its parts together, special attention in put on compatibility and component matching in order to achieve the expected performance. Additionally, a telecommunication solar power system installed at an unmanned site must be extremely reliable. It is necessary to operate satisfactorily irrespective the weather conditions and with the least human intervention. In the case of a malfunction, it is important to communicate and raise an alarm to the nearest manned station and to sustain the station's operation for a period long enough for the maintenance personnel to arrive. Under these view points, the technical parameters which are considered during the design phase refer to,

- system sizing and component matching
- minimisation of the loss-of-load probability
- unattended operation and very little service
- selection of high quality components
- operation under extremely harsh weather conditions (low winter temperatures, snow covering, gusty winds, moisture etc.)

Solar power systems for telecommunications have many advantages in comparison to other conventional power sources. In brief, these are:

<u>Reliability</u>
In stand-alone applications, very few other than solar power systems can match the reliability of an expertly designed and appropriately installed photovoltaic system. Solar electrification systems have no moving parts and thus, very little maintenance is required. Additionally, reliability in operation increases due to the non-existing fuel dependence.

<u>Convenience and Flexibility</u>
Solar power systems consist of small, light-weight components that are relatively easy to transport to any site. For the transportation and installation of photovoltaic generators and other system components the road infrastructure is not an important issue while, closeness to the electricity grid is not needed. Due to these reasons, the

use of solar power systems permits quite a free selection of site locations for repeater stations.

Modularity
A solar power system can be designed to suit the load requirements, including additional autonomy days according to a specific telecommunication application. Moreover, photovoltaic systems consist of modular components and the stations can be expanded without dismantling or replacing the vital parts of the system when extra loads are added.

Economy
A professional solar-powered system for a repeater station installed on a mountain peak covers a wider area in terms of telecommunication signals. In this way, the number of local stations required is minimised with obvious benefits in the overall costs and also indirect costs which arise from the use of conventional power sources.

Hybridisation
In particular low-irradiance sites or especially demanding applications with increased daily electrical loads, it may be beneficial to parallel a wind turbine with a solar array for simultaneous battery charging. For even higher loads, a diesel generator is usually included in a solar system to ensure 100% load coverage.

Figure 1: View of a solar-electrified telecommunication station

2.2 System Sizing

The sizing of the PV systems for the telecommunication applications reported herein was done by NESTE-NAPS, by using a special computer programme. Modifications, where needed, were carried out to account for microclimatic particularities of the sites. A general block diagram of a PV-powered telecommunication system is presented in Figure 2.

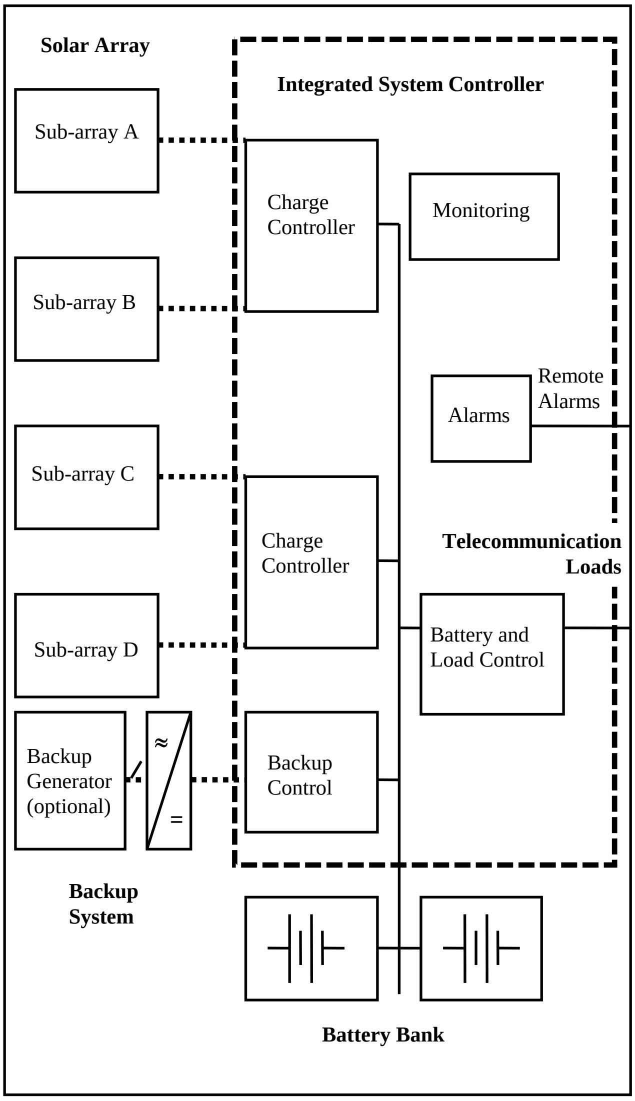

Figure 2: Layout of a solar-powered telecommunication system

2.3 Solar PV Generator

In general, the PV array is sized to satisfy the average daily load demand of the period with the lowest insolation. In this way, sufficient solar energy is available at all times of the year. The array inclination is always set for optimal performance during winter periods. Since it is usual that in the installation sites of telecommunication systems lightning strikes are quite often, special earthing devices are installed for lightning protection.

2.4 Battery Storage

The battery capacity is sized to cover the average daily load for the specified autonomy days, i.e. days without energy input from the PV array. Other technical parameters taken into consideration refer to battery capacity recovery from deep discharge and temperature control against freezing. The battery bank is always housed in special metallic boxes and they are protected against corrosion and extreme weather conditions. The batteries used in telecommunication solar-powered systems are vented lead-acid, single 2V cells with low antimony and tubular positive plates. This battery technology provides very good cycling characteristics, although water refill is necessary once or twice in a year depending on the location.

With aim to maximise the operational lifetime of the batteries, the following cycling conditions are taken into account in the design phase of a system:

2.4.1 Daily cycling
The battery capacity is calculated with respect to the load so that the discharge depth in a typical daily cycle does not exceed 10% of the nominal battery capacity (very shallow cycling). On the following day, the solar array is then supposed to fully recharge the battery.

2.4.2 Seasonal cycling
The ideal situation for a high autonomy requirement PV system would be that the solar array is capable of keeping the battery in a fully charge condition even in the worst solar insolation day in a year. This would certainly result in an oversized and costly system. In reality, PV telecommunication systems are designed to allow seasonal variation in the battery DOD up to 40% of the total battery capacity.

2.4.3 Autonomy cycling
During an unusually long low insolation period, the battery may suffer from deep discharge. In order to avoid irreversible sulphation of the battery cells and also to protect the battery from freezing, the cut-off threshold corresponds to 20% on the battery nominal capacity. In low SOC conditions, the dedicated controller is adjusted to send a low-voltage alarm signal to the corresponding central station.

2.5 Dedicated Controller

The controller in a solar-powered telecommunication station is a vital part of the overall system. A dedicated controller is designed to supply the load at all times and disconnect or reconnect the solar array to the battery storage when needed. The latter ensures that the battery is maintained in a good condition by controlling the charging rate and by preventing excessive overcharging or deep discharging. A dedicated controller also provides means for system supervision through its metering and alarm functions.

The controllers used in PV telecommunication systems in Greece are based on a specially designed 30A series regulator board. The solar array is divided in two or more sub-arrays and regulation for either lead-acid or nickel-cadmium batteries is available. Other features include:

- bistable relays for long life and low power consumption
- sub-array disconnection at night to prevent reverse current flow to the battery
- lightning protection
- automatic boost charge after a deep battery discharge
- independent adjustable set points for charge termination of each solar sub-array
- adjustable set points for low voltage load disconnect and load reconnect
- adjustable alarm set points and time delay
- adjustable set points to select 12V, 24V or 48V system operation mode
- monitor card that displays battery voltage, battery current, load current, array currents and high/low voltage alarm indication

Temperature compensation is also provided and it will automatically switch into a non-compensated mode should the sensor be removed or become non-functional.

3. TELECOMMUNICATION SOLAR SYSTEM APPLICATIONS IN GREECE

Over the last four years, there have been 29 new solar-powered telecommunication stations installed in 4 different areas in Greece. The overall nominal power of these systems is 31kWp.

3.1 Holy Mountain Monastic "State" (Mountain Athos)

The first solar power systems for telecommunications were installed in 1994 in the Holy Mountain peninsula which lies along the Athos part of Chalkidiki, North Greece. The unique Holy Mountain area still remains "Byzantium in miniature" and is certainly one of the most impressive institutions of Christian Orthodox heritage in the whole world. There are twenty monasteries, fourteen skits and hundreds of Celia (cells), all of which create the most impressive Byzantine legacy. As a result of the historic value and the cultural monastic tradition, the whole area of the Holy Mountain "State" is not electrified by the main grid.

In the past, there were major problems in telecommunications, especially during the winter periods. Back in July 1994, the Hellenic Telecommunications Organisation (OTE), funded 19 solar-powered outstation terminals, which appeared to be the most comprehensive solution in resolving permanently the problem. The whole project, including installation of special telecommunications equipment, was completed and commissioned in the beginning of 1995.

The size of each solar system depends on the load and varies from 0.4kWp to 1.8kWp. All loads are operating in 12Vdc mode and the total nominal solar power is 12.5kWp. Most of the systems have been installed in rough terrain and the transportation of the materials to the final destination was made by using mules. Particular attention was put on the aesthetical adoption of the systems in the environment.

Figure 3: A typical solar-electrified outstation at the Holy Mountain

The outstations serve through radio links and repeaters the central telecommunication station at Ierissos, which is the closest town. Each solar system has been designed for 10 days autonomy. The condition of the systems is continuously monitored through remote alarms by the central OTE station at Ierissos. The operation of all solar systems is satisfactory and the telecommunications network of the Holy Mountain peninsula is served adequately, even in the worst winter days.

3.2 Arcadia

A 2kWp stand-alone solar PV system located on a mountain peak in Arcadia, serves the telecommunication network of 16 villages in Peloponnese. This system operates at 12Vdc and provides energy for a repeater station. The complete system was installed and commissioned in September 1995.

3.3 Kalavrita and Mountain Dirfi Telecom Stations

Another telecommunications project was initiated in 1997 and refers to 9 solar systems for equivalent repeater stations. These systems were designed to operate at 48Vdc and are installed in distant mountainous sites with extremely harsh environmental conditions in winters. The battery storage requirement is 12-days autonomy. For another reason, the rough terrain and the difficult accessibility due to heavy snow, indicate for extra battery storage. Special care has also been taken in the metallic structures so as to be high enough not to be covered by snow and strong enough to withstand high wind speeds.

Since October 1997, a 2.5kWp photovoltaic system powers a telecommunication repeater which is installed close to the Helmos winter ski resort at Kalavrita.

Eight in all PV-electrified telecommunication systems of total nominal power 14kWp, were installed at different sites on mountain Dirfi in central Evia. They are in operation since December 1997, while the last was commissioned in April 1998.

Figure 4: A 2.4kWp PV system for a repeater station at mountain Dirfi, central Evia

4. CONCLUSIONS

This paper reported on the design and operation of solar-powered telecommunication systems in Greece. The owner of the systems is OTE and system design and commissioning was done by SENERS Ltd. in co-operation with NESTE Oy. Reference was given to special features of stand-alone PV system sub-components, such as the solar array, the batteries and the dedicated controller.

The operational experiences of the Holy Mountain and the other systems over the last 3 years has shown that photovoltaics is a reliable power source and an economically viable solution for stand-alone telecommunication stations. The market experience in Greece also indicates that Telecom companies, particularly OTE, invest in PV technology even without co-funding from National or other programmes.