# Load management in remote-area power-supply (RAPS) systems*

**A. Walton**
*Department of Electrical Engineering, James Cook University of North Queensland, Townsville, Qld 4811 (Australia)*

(Received October 25, 1990)

## Abstract

Design criteria for hybrid RAPS systems are generally written in terms of the sizing of the various components of the system to provide both the instantaneous maximum power demand and the daily energy requirements of the installation Most effective use of each component part of the system must be achieved in order to optimize the utilization of the plant and achieve maximum economy Implementation of such load management schemes demands the installation of some intelligent interface between the source and the load This is usually some form of microprocessor controller that can be programmed to disable different types of load under different circumstances of supply/demand to limit the maximum demand on the system The requirements of these controllers and the improvements to be expected from their installation are discussed

## Introduction

It is axiomatic that in all RAPS systems there is a basic requirement to use energy very effectively. Unlike consumers connected to a reticulated supply, where there is unlimited power at the touch of a switch and energy conservation is not of paramount importance, the limited capacity of RAPS systems makes the consideration of overall energy usage very important

As always, it is the maximum instantaneous power demand and the total energy usage (usually over one day) that set the basic requirements for the size of the elements in the system, i e., the size of the generator and the capacity of the battery storage required In all situations, it is assumed that the base system for comparison is that of a stand-alone diesel generator set that runs whenever electricity is required. Under such conditions, the generator may be operating at low load, and therefore at low efficiency for much of the time

## Configurations of RAPS systems

The scope for managing the load is, to some extent, dependent upon the type of system being used. This is because the elements of the system being controlled or selected may influence the type of scheme implemented.

*Paper presented at the Workshop on the Development and Management of Battery Systems for Energy Storage, Brisbane, Australia, October 25–26, 1990

0378-7753/91/$3 50 

*Diesel/battery/inverter systems*

The most basic RAPS system is that shown in Fig. 1 where the output of the diesel-driven generator is rectified to charge the batteries and the energy stored in the batteries is passed through the (normally sine-wave) inverter to provide the a.c. power for the home. The advantage gained by running the generator at full load, irrespective of the instantaneous load, improves the efficiency of the system. The efficiency of the rectification must be high so as not to nullify the high efficiency of generation achieved by running at maximum load A modification to this system is to allow the output of the generator to be switched, as shown by the broken lines in Fig. 1, so that it can either supply the load directly or charge the batteries

The operation of the system can be improved even further if control equipment is included to allow the diesel generator and the inverter to be synchronised The instantaneous maximum power available is then the sum of the individual output powers from the battery via the inverter and the generator While not in itself a form of direct load control, incorporation of this facility can be a very significant operational feature and can well overcome less attractive measures of actual load control or load shedding.

Naturally, should some form of alternative energy be available i.e , solar or wind, this can easily be incorporated into the system to provide additional charge for the batteries at the appropriate place in the system

*Diesel/battery/inverter–rectifier systems*

The significant difference in this system is that a fully controlled inverter–rectifier unit is used instead of separate rectifiers and inverters. This is outlined in Fig. 2 where it can be seen that the generator can once again be synchronised with the inverter on the a.c. side, with, of course, the batteries connected to the d.c. side.

The difference between this inverter and the previous one is that the firing of the thyristors or transistors is fully controlled over 360 degrees, which enables it to be operated as both a rectifier and an inverter. Also, the power supplied by the generator, but not utilized by the load, can be converted to d.c. and stored in the battery. Once again, if the efficiencies

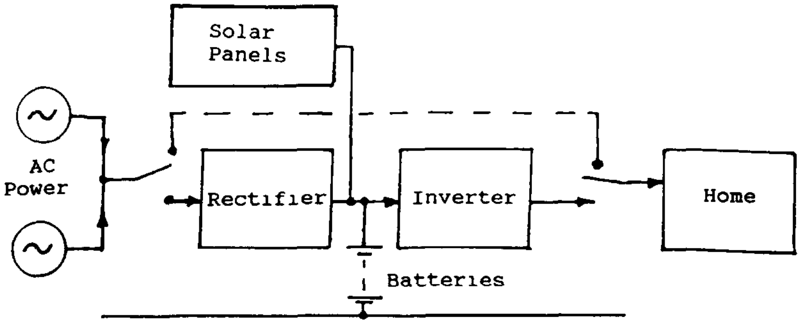


Fig 1 Diesel/battery/inverter RAPS system

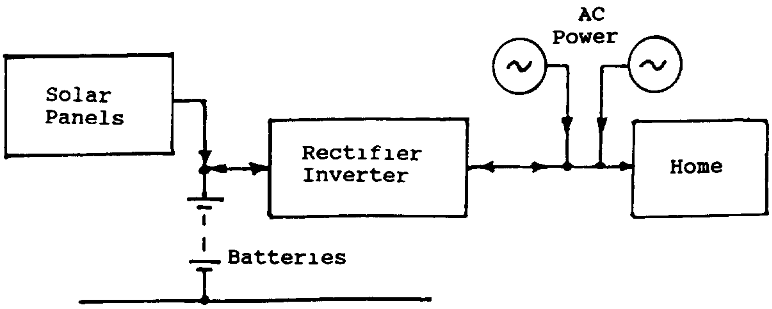


Fig 2 Diesel/battery/inverter–rectifier RAPS system

of rectification and inversion are high, even greater use can be made of the energy available

It is assumed that the generator is programmed to run for periods sufficient to ensure that the batteries are kept at an optimum charge condition such that the normal, or expected, load to be supplied each day does not require the running of the generator by necessity.

The operation of the whole system must be under the control of some sequence controller, most commonly in the form of a propriety programmable logic controller (PLC) The PLC can be programmed to monitor the level of the battery voltage and make logical decisions on the condition of the batteries, the control of the load supplied, and whether to run the generator.

## Load management

*Load types*

In any kind of management scheme for the supply of power to a consumer, it is necessary to categorise the loads, separate the connections to them, and devise an algorithm that decides on what basis some loads should be disconnected but supplies to others should be maintained. Decisions of this type are normally made with regard to the state-of-charge (SOC) of the batteries, but this is not necessarily the only consideration to bear in mind. For example, it should be determined whether a load should, in fact, be switched off at all; the alternative being to run the generator, supply more charge to the batteries, and support the overall system.

Naturally, when there is a system requirement to shed load, the types of load being supplied need to be classified. It is reasonable to consider three categories of load as follows:

(i) primary loads, e.g., food refrigeration and/or freezing requirements;
(ii) secondary loads, e g., security lighting, television, radio, toaster, etc.;
(iii) tertiary loads, e.g., aesthetic/luxury items, decorative lighting, etc

*Load control strategies*

It is expected that the load pattern will correspond to the normal diurnal curve, and decisions on load limitation will therefore vary according to the time of day. When the battery is fully charged, all of the house load can be supplied. As the battery SOC falls, the battery voltage drops and it may then be necessary to impose limitations on the load that can be supplied

Assuming it has been possible to segregate the wiring to the circuits to enable the shedding of individual loads, a strategy along the following lines, determined by the level of the battery voltage, could be devised. Knowing the maximum and minimum battery voltage levels to be observed, three levels of battery voltage at which load shedding should occur could be set. The load shedding could be automatic or could be done with some degree of intelligence with regard to the overall charge/discharge sequence of the battery. While the primary load is the most important of the three load categories, it is also made up of intermittent individual loads that do not therefore contribute to a major continuous load burden. It may be quite reasonable simply to delay the supply to such loads so that they are enabled only during periods of low total system load.

For secondary and tertiary loads, the load shedding could be automatic but there is no difficulty in educating users to enforce simple management requirements to obtain maximum utilization of the systems. It is, after all, in the interests of users to optimize system operation and, with minimal training, users can be more competent than a PLC programmed with the very best of intentions At Granite Vale, Queensland, where a 6 kV A system has been operating for some time, there has been no difficulty whatever in the consumers restricting simultaneous usage of small cooking equipment to avoid tripping the inverter. To them, the luxury of having continuous electric power far outweighs any inconvenience of this type.

## Conclusions

Whilst it is certainly possible to implement a controller that switches sections of load to maintain continuous power from RAPS systems, it is found that customers find no difficulty in adapting to the mild limitations placed on them. The function of PLC controllers, and the like, are therefore relegated to generator and battery management rather than to load management The advantages gained from the installation of a RAPS system is worth so much to the consumer that, generally, a basic common-sense approach to load management is all that is needed.