



## Optimum operation strategy and economic analysis of a photovoltaic-diesel-battery-mains hybrid uninterruptible power supply

M. Ashari<sup>a,b,\*</sup>, C.V. Nayar<sup>a</sup>, W.W.L. Keerthipala<sup>a</sup>

<sup>a</sup>*Centre for Renewable Energy and Sustainable Technologies Australia (CRESTA), Curtin University of Technology, Perth 6845, Australia*

<sup>b</sup>*Department of Electrical Engineering, Faculty of Industrial Technology, Institute of Technology Sepuluh Nopember (ITS), Surabaya 60111, Indonesia*

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### Abstract

This paper presents the optimum operation strategy and economic analysis of a photovoltaic-diesel-battery-mains hybrid uninterruptible power supply (UPS). The system involves a photovoltaic, battery and bi-directional inverter that is connected in parallel to the grid. A diesel generator is required when the grid is not available for a longer time. The optimum operation strategy of the system is proposed for the diesel-connected mode (when the grid fails for several hours), while the economic analysis is evaluated for the grid-connected mode. The optimum strategy determines the 'set point' value for starting and stopping the diesel generator, resulting in a lower system operation cost within its lifetime. The optimum value is obtained by comparing the cost of the diesel fuel consumption and the battery wear. The economic analysis includes the system operation as UPS and demand side management. The system will reduce the power flow from the mains by increasing the power from the inverter to the load when the tariff is high. However, when the grid tariff is low, the power from the mains is used to charge the battery and to meet the load simultaneously. © 2000 Elsevier Science Ltd. All rights reserved.

*Keywords:* Uninterruptible power supply; Mains; Battery storage; Diesel generator; Photovoltaic

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\* Corresponding author. Curtin University of Technology, Centre for Renewable Energy Systems Technology, Australia (CRESTA), GPO Box U 1987, Perth, WA 6001, Australia. Tel.: 61-8-9266-3157; fax: 61-8-9266-3107.

*E-mail address:* eashari@cc.curtin.edu.au (M. Ashari).

## 1. Introduction

Uninterruptible power supplies (UPS) are used to interface critical loads such as computers and communication equipment to a utility power grid. A new UPS topology that involves photovoltaic, diesel and battery/converter has been presented by Nayar et al. [2]. This system has also been tested and implemented in India [3]. The configuration of the PV/Battery/Mains hybrid UPS is presented in Fig. 1. When the grid suddenly fails, the inverter will take over to supply the load without any interruption of power. The diesel generator (DG) may be used if the grid is not available for a longer-term e.g., for several hours.

When the grid is normal, the system can also function as a demand side management (DSM) besides as a UPS. The DSM is a method to eliminate the variation between the high load demand and the low period [5]. Fig. 2 illustrates the basic principle of the DSM. The system will reduce the power flow from the mains when the tariff is high, during 11.00 a.m. to 3.00 p.m. The system will discharge the battery and the inverter will supply most of the power demanded. However, when the grid tariff is low, the power from the mains is used to charge the battery and to meet the load simultaneously.

This paper presents the optimum operation strategy for the diesel-connected mode (during the grid failure for several hours) and the economic analysis for the grid-connected mode, particularly in Perth, Western Australia.

## 2. Optimum operation strategy for the diesel-connected mode

The operation of the entire system is controlled using the ‘set point’, a reference value for connecting/disconnecting the grid, turning-on/off the diesel generator and other components. The set point value is calculated on the bases of a certain percentage of the component rated power, the system load or the battery state-of-charge (SOC). Table 1 resumes the typical set points and the ranges.

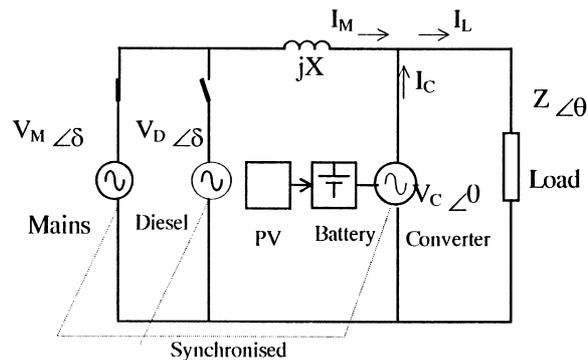


Fig. 1. System configuration.

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