OPERATION AND CONTROL OF ISLAND SYSTEMS – THE CRETE CASE

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Abstract - In this paper, an advanced control system for the optimal operation and management of isolated power systems with increased renewable power integration is presented The control system minimises the production costs through on-line optimal scheduling of the power units, taking into account short-term forecasts of the load and the renewable resources. The power system security is supervised via on-line security assessment modules, which emulate the power system frequency changes caused by pre-selected disturbances. For each of the above functions, a number of techniques has been applied both conventional and AI based. The system has been installed in the Dispatch Center of Crete since June 1999, and is currently under evaluation.

Keywords Isolated systems, operation and control, and operationSteady state security assessment, EMS, on-line evaluation, fuzzy classifiers, contingencies

1. INTRODUCTION

Isolated electrical power systems face increased problems related to their operation and control. In general, the customers of these systems face higher costs and poorer quality of supply than the customers of large interconnected systems The high costs are due to the imports and transportation of oil that is frequently used as fuel for the thermal generating units, often diesel units and gas turbines. The production of electric energy from renewable energies, mainly wind, presents therefore increased interest, especially when important wind energy potential exists. Significant displacement of conventional fuels can therefore be obtained by a high wind power penetration. In this case however, it is important to ensure that the electric power system operation will not be adversely affected by an increased connection of this volatile form of energy in the system. The objective of a European Commission R&D project [1], named as *CARE*, was to develop an advanced control system aiming to assist operators of isolated power systems by proposing optimal operating scenarios for the various power units, as well as the various actions needed to avoid dangerous situations, which might result from a poor prediction of load or wind or in case of preselected disturbances.

The control system minimises the production costs through on-line optimal scheduling of the power units taking into account the technical constraints of the thermal-units and short-term forecasts of the load and the renewable resources. The power system security is supervised by on-line security assessment modules, which based on the proposed scheduling of the power units check the acceptable limits of frequency variations, in case of perturbations caused by both the renewable and conventional power sources.

For each of the above functions, a number of alternative technologies have been developed, both conventional and AI based. In the following, these technologies are briefly described with special emphasis on the AI technologies. The various modules, that perform the control functions, have been integrated in the CARE control system software and equipped with a user-friendly man machine interface A prototype of CARE has been interfaced to the on-line SCADA Data Base of the Control Center of Crete, , since June 1999. CARE is currently in daily operation undergoing thorough evaluation. Initial results however, have shown satisfactory forecasting results, clear economic gains provided by the economic dispatch advice and timely and accurate assessment of the dynamic security.

2. THE POWER SYSTEM OF CRETE

The conventional generation system of Crete consists of two major power plants comprising 18 thermal, oil-fired generating units with a total installed capacity of 522 MW. These plants are located near to the major load points of the island. The generating units are grouped in 6 Steam units of total capacity 103.5 MW, 4 Diesel units with 48 MW, 7 Gas turbines with 185 MW and one combined cycle plant with 132 MWs. The annual peak load demand is close to 390 MW. The base load is mainly supplied by the steam and also by the Diesel units. The gas turbines normally supply the peak load at a high running cost, that increases significantly the average cost of the electricity being supplied. The transmission network consists mainly of 150 kV circuits and, to a less extent, of 66 kV circuits.

The new legal framework introduced in Greece in 1995 dealing and regulating the electricity production from renewable sources has provided a significant stimulus to the installation of Wind Parks in the islands. As a result, 11 Wind Parks with an installed capacity of more than 80 MW are being or are planned to be installed in Crete by the year 2000. All the wind parks, with few exceptions, will be installed at the eastern part of the island, that presents the most favorable wind conditions. As a result, in case of faults on some particular lines, the majority of the wind parks will be disconnected. Furthermore, the protections of the WTs might be activated in case of frequency variations, decreasing additionally the dynamic stability of the system. Extensive transient analysis studies have therefore been conducted in order to assess the dynamic behavior of the system under various disturbances and with different combinations of the generating units.

3. THE CARE SYSTEM ARCHITECTURE

The functions developed and integrated in the CARE control system structure, are shown in Figure 1. After extensive testing and evaluation of the calculation burden of each module, the basic time step was fixed to 20 minutes for all the activities (forecasting, security assessment, unit commitment and economic dispatch). Unit commitment has an horizon of 8 hours ahead (moving window), but tests showed that an outer cycle of 48 hours was needed to define guidelines that take into account the daily cycle of the load. The functions are performed periodically as shown in the flow-chart of Figure 2. In the next Sections, the main modules of the system are described.

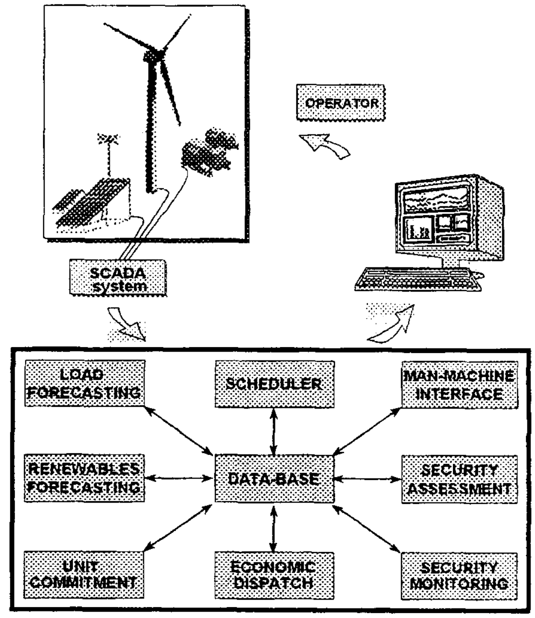

Figure 1 : *The CARE system architecture.*

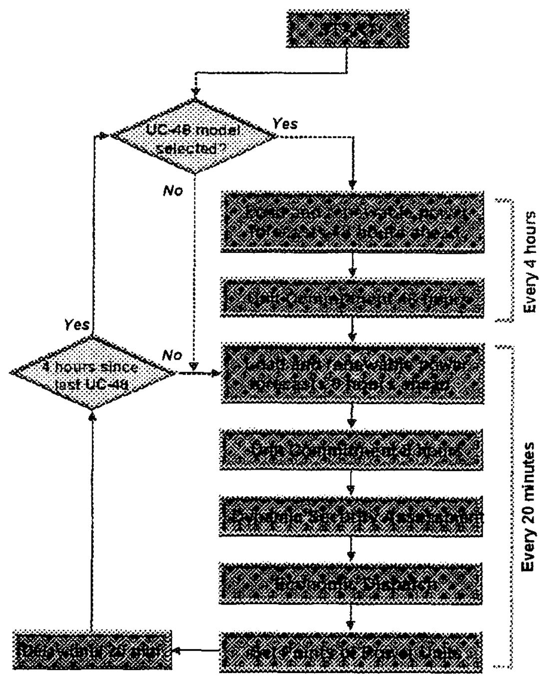

Figure 2 : *Main operations of the CARE system algorithm.*

4. FORECASTING

4.1 Load Forecasting

Load forecasts are required for both short (several minutes up to several hours ahead) and long time scales (of the order of several hours ahead up to several days ahead), in order to provide input to the economic dispatch and unit commitment algorithms. The modules developed include:

(i) same time the previous day (scaled for errors between days),
(ii) same time the previous week (scaled for errors between days).
(iii) linear ARMA and,
(iv) fuzzy neural networks.

Each forecasting module was evaluated against persistence forecasts using Crete load data for past years. The fuzzy neural network model has exhibited the best performance for the case-study of Crete with an average error (MAPE) of 3% for both common and special days.

4.2 Wind Forecasting

Three basic methods have been developed:
(i) linear ARMA models,
(ii) linear ARMA and fuzzy-neural network models,
(iii) fuzzy neural network based on geographically distributed wind data.

The methods have been evaluated against persistent forecasts using the wind speed time series data collected on Crete and also using a 364-day database of 1-minute wind speeds from other islands. For the wind forecasting models, a generic architecture was implemented, so that CARE becomes able to integrate meteo-based forecasts in a future stage of the project.

5. UNIT COMMITMENT

Two modules have been developed:
(i) A module based on Genetic Algorithms (GAs), both for the 8 hours and the 48 hours horizons. This approach provides a relatively short computation time, while constraints of the various kinds of generators and security spinning reserve restrictions can be easily included.
(ii) A combinatorial Unit Commitment module for both cycles. The current operating practice of the Utility was closely followed. Temperature forecasts were used to determine the maximum available power of the gas turbines.

6. ECONOMIC DISPATCH

Four modules have been developed:
(i) A module based on Evolutionary Programming providing a number of advantages over common Genetic Algorithms.
(ii) An Optimal Power Flow module based on Constrained Linear Programming. Particular emphasis was given to the feasibility and deficiencies concerning a large penetration of wind power and the operation of Independent Power Producers (IPPs) under three alternative operation modes, i.e. fixed schedule, fixed penetration and economic schedule.
(iii) One module based on Genetic Algorithms (GAs). This module was tested against the traditional lamda-iteration method, based on the concept of equal incremental cost, providing results with an absolute relative error between 0.001% and 0.04%.

7. SECURITY ASSESSMENT

The outcomes of these modules are rules and security functions to be used for the prevention of insecure dispatching recommendations to the operator (preventive mode) and for on-line security monitoring. Purely AI methods were applied involving creation of a learning set and the derivation of rules and security functions.

7.1 Generation of the Learning Set

A unified Learning Set for three disturbances on Crete specified after discussions with the Utility. It comprised approximately 3000 Operating Points covering various loading conditions (low-, medium- and high-load) characterized by the maximum frequency deviation and the maximal rate of frequency change.

7.2 Development of Security Rules and Procedures

Three methods have been applied:
(i) Decision Trees producing security rules of "if...then...else" type. For each disturbance very compact DTs have been produced with very good performance.
(ii) Kernel Regression Trees able to provide security classification results of similar performance and in addition emulation of numerical security indices.
(iii) Artificial Neural Networks with one output layer comprising the two security indices as outputs

8. INTEGRATION

A relational database structure was developed using the facilities provided by ACCESS. All software modules described in the previous Sections have been incorporated in the CARE package and interfaced according to the two execution cycles shown in Figure 2. The various modules exchange their inputs and outputs via the CARE database, which is updated by the SCADA database every minute. The facilities provided by VISUAL BASIC have been used for the completion of this task. A user-friendly man-machine interface has been provided comprising the display of all essential information graphically on a single screen, while a number of "windows" is available on call to provide explanatory information or other results.

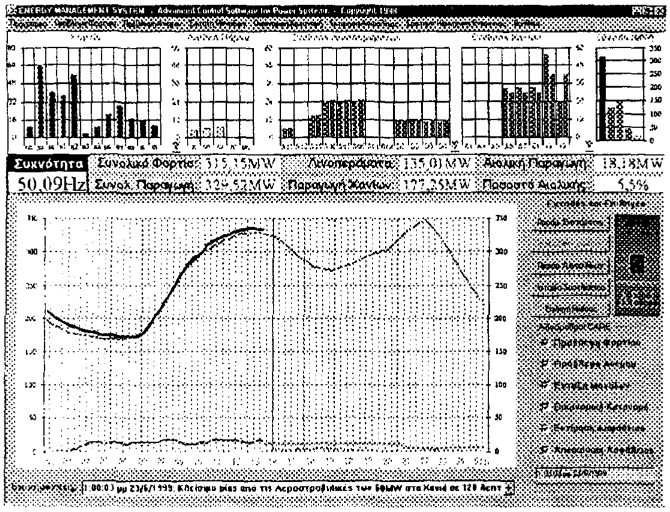

Figure 3. The main CARE Window

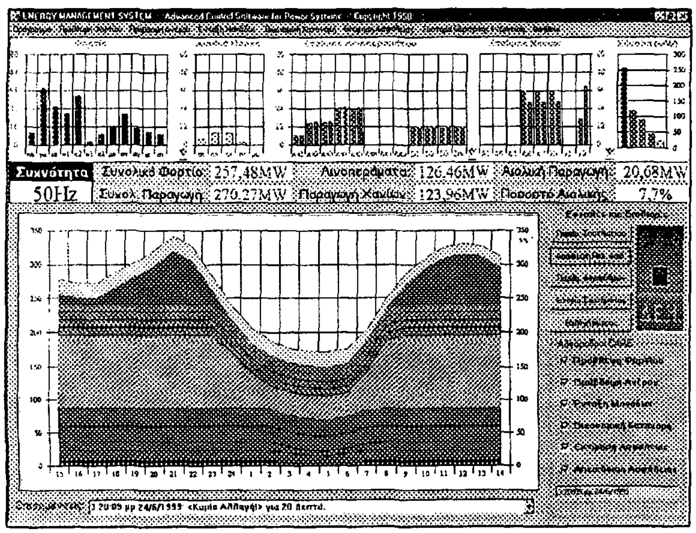

Figure 4. Unit Commitment results for 48 hours ahead.

The information permanently displayed provides the current state of the system (production and load), production, load and renewable forecasts for 12 hours ahead contrasted to historical values of similar days selected by the user. (Figure 3). The main screen is divided in 4 parts. The upper part provides an overview of the current operating state of the system as refreshed every minute by the SCADA on-line database. The flowcharts display active demands, wind park productions, current generation of the conventional units in the two thermal power stations and finally a summary of the system load, the production of the thermal units according to their type (Diesel, Steam and Gas) and the total Wind Parks production. The central window provides load and wind power forecasting compared to historical data. This window spans a period of 24 hours and is divided by a hypothetical vertical line in the middle of the screen. The left part of the screen shows the total load and wind power production for the past 12 hours, while the *right part* displays forecasts, optionally contrasted to past load values. In the right part of the screen the commands and options for the easy adaptation and parameterisation of the CARE software are shown. These commands allow the determination of which thermal units are available for dispatch, as well details of the units in operation. The privileged user has the ability to specify which of the modules will be executed every 20 minutes or 1 hour and even decide which of the available modules will take care of each activity. Under the central window commands and information to the operators and other warning messages are prompted.

Additionally, two main windows are available "on call". These are:

- Unit Commitment results for 48 hours ahead (Figure 4).
- Dynamic Security Assessment results for 48 hours ahead, displayed in the form of frequency deviations in case of the considered disturbances under the predicted load demand and wind production.

9. CONCLUSIONS

The paper presents the main issues of CARE, an adaptable advanced control software that achieves optimal utilization of renewable energy sources, in medium and large size isolated systems with diverse structures and operating conditions by advising operators of possible actions. The insurance of increased security and reliability of the system will allow maximization of renewables penetration. The provision of various AI modules together with traditional approaches and the flexible Man-Machine Interface allow selection of the most suitable algorithms and convenient adaptation to medium and large size islands of various structures and operating conditions. A prototype of CARE has been interfaced to the on-line SCADA Data Base of the Control Center of Crete. Initial evaluation of this pilot installation has shown satisfactory forecasting results, clear economic gains provided by the economic dispatch advice, timely and accurate assessment of dynamic security.

References

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