MORE CARE Overview

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Abstract – **This paper provides an overview of MORE CARE, a European R&D project financed within the 5th Framework Energy Programme. This project has as main objective the development of an advanced control software system, aiming to optimize the overall performance of isolated and weakly interconnected systems in liberalized market environments by increasing the share of wind energy and other renewable forms, including advanced on-line security functions. The main features of the control system comprise advanced software modules for load and wind power forecasting, unit commitment and economic dispatch of the conventional and renewable units and on-line security assessment capabilities integrated in a friendly Man-Machine environment. Pilot installations of advanced control functions are foreseen on the islands of Crete, Ireland and Madeira.**

Index Terms— **Utility-Integration, Control Systems, Forecasting Methods, Operational Planning, Security Assessment.**

I. INTRODUCTION

The population of EU islands is about 12 million persons without taking into account the British islands and Ireland. These islands are characterized by high costs of electricity production because they are based on imported fuel, mainly diesel. The import costs are further increased by the cost of transportation. On the other hand, many islands possess a significant potential of local resources of wind and solar energy, which, if used to produce electricity, contributes to their economic development and moreover helps protecting their fragile environment. However, there is a number of technical problems limiting this strategy: the grid is relatively weak, wind is a volatile power source, reserve needs to be a high percentage of the installed power and security might face increased risks. In consequence, these systems tend to be managed in a conservative way that under-exploits the renewable energy sources and increases the already large costs of electricity in islands. Alternatively, the system might be operated with lower security margins. Advanced control systems can substantially help operators to manage efficiently these systems allowing increased penetration of renewable energy sources in a secure way, as shown initially in [1]. In particular, the advanced control system "*CARE*" has been developed previously and installed in Crete, an island with a peak load exceeding 400 MW and more than 60 MW of installed Wind Power [2].

The objectives of MORE CARE, financed within the Energy Program, (Contract ERK5-CT1999-00019) are to produce enhanced capabilities of the CARE software. This aims at optimizing the overall performance of isolated and weakly interconnected systems in liberalized market environments by increasing the share of wind energy and other renewable forms, taking into account pumped hydro storage facilities and providing advanced on-line security functions, both in preventive and corrective mode.

More specifically, the work comprises collection and analysis of renewable, electrical and operating data and identification of the needs for the following developments of on-line control functions:

Paper accepted for presentation at the 3rd Mediterranean Conference and Exhibition on Power Generation, Transmission, Distribution and Energy Conversion MED POWER 2002, jointly organized by National Technical University of Athens, IEE Hellas, Israel and Cyprus, Athens, Greece, November 4-6, 2002

- Improved wind power forecasting modules for short-term (0-8 h) and medium time (4-48 h) horizons.
- Hydro power forecasting functions.
- Unit Commitment and Economic Dispatch modules that take into account the availability of hydro-storage, liberalized market conditions and increased security conditions.
- On-line security modules that provide both preventive and remedial advice in case of predetermined disturbances.
- Installation of the enhanced and new forecasting, operational planning and security modules on Crete, in order to face the new operating conditions.
- Installation of the enhanced and new forecasting, operational planning and security modules on Madeira, in order to face effectively the operating conditions with very high wind power penetration.
- Development of wind power forecasting modules for the power system of Ireland.

In this paper a general description of the software, including functionalities, general constraints, the characteristics of the user, operational environment, etc. are provided. Algorithmic details about the developed functions are provided in the accompanying papers in this Conference.

II. The *Care* System Architecture

The MORE CARE system aims to assist the operators of island 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 weather or pre-selected disturbances. The insurance of increased security and reliability of the system will allow maximization of renewable penetration. The product under development includes various modules of forecasting, operational planning and security assessment. Due to the diverse needs of targeted medium and large scale systems, the software under development is highly modular, allowing integration of the options that are best suited to the particularities of each system.

Fig. 1 shows the general CARE system architecture, also retained in the MORE CARE system and the various functions that will be implemented. Figure 2 shows the execution cycles and the succession of the MORE CARE modules to generate the power system operation schedules. This flow-chart is appropriate for relatively larger systems comprising steam and diesel or gas units. The power system of Crete is typical of such island systems. Units requiring both longer and shorter scheduling times characterize these systems, therefore both longer and shorter horizon forecasts and unit commitment functions are included. For island systems comprising only diesel units or gas turbines, e.g. the Madeira system, it is possible to simplify these execution cycles.

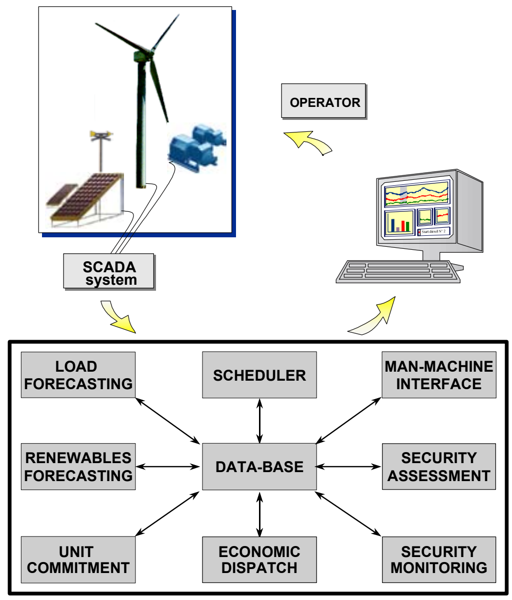

Fig. 1: *The CARE system architecture.*

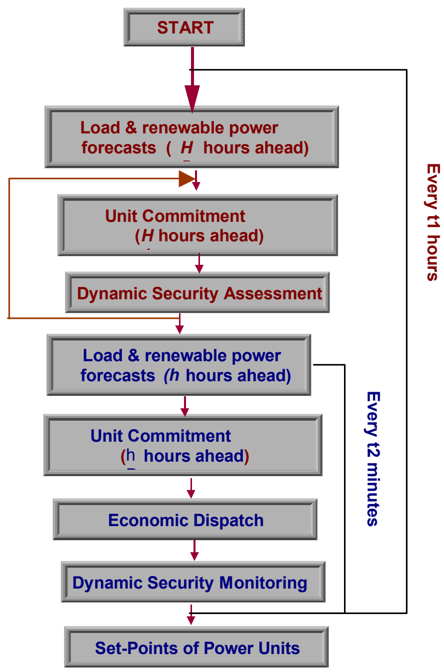

Fig. 2 **:** Main operations of the MORE CARE system algorithm. (For the pilot control installation of Crete it will be :H=48 hours, h=4 hours, t1=1 hour, t2=20 minutes.)

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.

Security assessment follows the unit commitment and dispatch modules, leaving to the operator the decision whether or not he wants to activate the module for validation of the proposed dispatch (or pre-dispatch resulting from the unit commitment). In this case, another solution will be presented to the operator, if the first is considered insecure.

In the next sections, the main modules of the system are described.

III. Load Forecasting

In order to perform the Unit commitment and Economic Dispatch functions for the next planning horizon, it is necessary to have a forecast of the profile of the total load of the power system for this horizon. As "forecasted load profile" is characterized a set of consecutive spot forecast values as well as confidence intervals for these forecasts.

Usually in conventional systems forecasts are produced once per day. In autonomous systems with high penetration, it is necessary to update forecasts several times per day.

Several methods are being developed for the LF task:

1. *Simple forecasting*

A simple algorithm has been implemented using the load value from the same time the previous week, scaled by a factor representing the change in load between the two weeks.

2. *Fuzzy neural network model*

This model receives past load values to produce forecasts for the next 48 hours. The model parameters are adapted as new data arrive. Special attention is paid for predicting the load of weekends and special days. Temperature forecast is not considered as input to the model since such data is not available. However, the model compensates on this factor through auto-adaptation. The model produces hourly forecasts.

3. *ARMA model*

This model is an autoregressive model.

All the above methods have been integrated in the LF-module. However, when the software runs on-line only one method will provide forecasts to the rest of the modules (UC, ED) of the MORE-CARE software.

IV. Wind power forecasting

- The purpose of the Wind Power Forecasting (WPF) module is to provide forecasts for the power output of each wind farm connected to the power system, as well as the corresponding confidence intervals. Forecasts are required by the ED and UC functions of MORE CARE software.

The following methods have been developed:

1. Simple Forecasting

Persistence consists on using the most recent value of wind speed or power as forecast for the entire planning horizon. Instead of using Persistence, one can use averages of past values as predictors (Naive predictors). Off line analysis permits to define the outperforming simple method for each case study.

2. Linear ARMA models

3. Fuzzy-neural models

Fuzzy autoregressive models are applied to predict wind speed or power up to 8-10 hours ahead. The input is past wind speed or power values as well as exogenous input (i.e. wind direction). The model parameters are self-adapted as new data arrive. Several tests using wind speed or power time series have shown that fuzzy logic based models outperform persistence.

4. Meteorological information based model A

A long-term (up to 48 hours) wind power forecasting module has also been developed. The module will be as adaptable as possible to varying availability of input data. To achieve the long term forecast, data input from a meteorological forecast model (HIRLAM), is required for one or more wind farms in the system. To make a shorter term, statistical correction, on-line SCADA data is required for one or more wind farms in the system. Where no time series input data is available for a wind farm, multipliers are be used to estimate the output from neighboring locations. This feature is also useful in the event of temporary communications problems.

5. Meteorological information based model B

This module makes site-specific wind speed forecasts based on the information produced by the SKIRON system of the Atmospheric Modeling & Weather Forecasting Group of the University of Athens. The SKIRON meteorological forecasts cover a grid of 15x15 km of Crete.

The operator will have the possibility through the MMI, to choose any of the above methods for on-line use. Special attention is paid to combine the short-term and long-term wind forecasts provided by the statistical and meteorological models, respectively.

V. Unit Commitment

The objective of the Unit Commitment (UC) function is to determine the combination of production units that will supply the expected demand of energy over the future period in question. This combination is the result of an optimization procedure that takes into account economic criteria and is subject to different types of economical, technical and security constraints.

The UC module of the MORE CARE software suggests to the operator of the power system a secure operating scenario for the next hours. In an interconnected power system, Unit Commitment is performed usually once a day or more, and is based solely on load forecasts. In isolated systems with high penetration from renewable (i.e. >20%), it is necessary to update regularly the proposed Unit Commitment schedules in order to account for the variability in the production of the renewable. Thus, the UC models developed operate in a "*sliding window*" scheme. The length of the look-ahead time (*planning horizon*) depends on the type of the installed power units. On operator's request, the operating restrictions will include preventive control measures on the UC module, coming from the security assessment module.

Two models are developed within the MORE CARE project for the UC task. Both models are based on Genetic Algorithms (GA) and are able to simulate systems with steam units, gas turbines, diesel and combined cycle power units including renewable like wind farms and small hydro stations. The operator will have the possibility to select one of them for on-line use.

VI. Economic Dispatch

The objective of the Economic Dispatch (ED) function is to distribute the load among the generator units selected in the Unit Commitment so that the total cost of the power system operation is minimized. The ED function is performed only for the *basic time-step* (e.g. 20 minutes ahead) of the planning horizon in order to provide the generators *set-points* to the operators.

The ED module is possible to compute the optimal generation production satisfying constraints of circuit loads, bus voltages and reactive generation to satisfy the load demand and losses of the system. It can also consider constraints related to bilateral contracts and *independent producers* of renewable power sources according to specific terms and conditions. On operator's request the output of the Economic Dispatch module (set-points) can be checked against *security constraints* with the security monitoring module, but these constraints will not be fed back as input to the ED modules.

Two different approaches are developed in MORE CARE to perform the economic dispatch function.

1. *Optimal Power Flow based on Linear Programming*

This module uses a linear model of the power system, which relates the generation production rescheduling and the other control resetting to the operating cost and the transmission network constraints. For the operation of a conventional unit the operating cost is specified by a cost curve expressing either running cost, or bidding price in case of open market operation.

2. *Genetic algorithms technique*

The Economic Dispatch module based on GA uses a real-coded genetic algorithm to minimize the operating cost while satisfying operating limits (ramp rates included), power balance and network constraints (optional).

VII. ON-LINE DYNAMIC SECURITY

In autonomous power systems, dynamic security assessment is a key issue in the operation and management of the networks. Sudden changes of system operating conditions must be quickly and efficiently compensated by generators to avoid frequency excursions or high df/dt variations, which may trigger the operation of system frequency relays, like under frequency protection relays of generators, provoking system collapse. This means that expected system frequency excursions and df/dt values, for some disturbances, must be assessed in a fast way to help in defining the more robust operating strategies. In addition, under- or over-voltages might disconnect generation and have to be guarded against.

On-line dynamic analysis of system behavior for a number of pre-specified disturbances is practically impossible using conventional tools. "Learning from examples" techniques, e.g. Decision Trees (DT) or Artificial Neural Networks (ANN), are used to provide accurate and fast evaluation of system stability by defining security rules and security functions. These structures need to be extracted from a "Learning Set" and can be used for on-line monitoring of the appropriately defined security margin and as security restrictions in the UC and ED modules, in order to arrive at the most economic and secure operating strategies. Two main approaches are developed for the fast security assessment task:

1. *Decision Trees Method*

The Decision Trees method, uses an inference inductive procedure, and derives classification structures of the type "*if-then-else*", able to provide a fast secure or insecure classification of each operating point. The DTs provide an overview and understanding of the dependence of the system's security on its pre-disturbance state. They are suitable for corrective control purposes. Thus, if the proper control variables are used as candidate attributes, they are able to provide explicit and quantitative information about the actions to be taken, if a potentially unsafe operating state is detected. The DTs are readily converted to a set of rules that can be very easily stored and incorporated in the security assessment software.

2. *Artificial Neural Networks Method*

The Artificial Neural Networks (multi-layer perceptron type), uses as inputs relevant system attributes to provide as output an emulation of the system robustness degree for the disturbances under analysis, i.e. the frequency deviation and the derivative of frequency relatively to time (df/dt). A previous feature selection stage is performed to select from the initial set of characterizing features the most relevant ones that are less correlated among each other. A new approach is used here for this purpose, consisting in exploiting sensitivities of the outputs of an initial ANN, relatively to the input variables.

VIII. CONCLUSIONS

This paper presents the main features of MORE CARE, an advanced control system that aims to provide advice to power system operators for the optimal operation and management of isolated power systems with large integration from renewable power sources. A number of different models for performing each main task have been integrated in the pilot installation of Crete, Madeira and Ireland.

IX. References

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