Energy Management System Design Considerations aiming towards
100% RES ENERGY SUPPLIED COMMUNITIES

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ABSTRACT: THE PURPOSE OF THIS PAPER IS TO PRESENT SOME DESIGN CONSIDERATIONS FOR ENERGY MANAGEMENT SYSTEMS THAT CAN LEAD TO 100% RES ENERGY SUPPLY FOR SMALL COMMUNITIES. IN THIS APPROACH, THE DIFFERENT PRODUCTION, STORAGE AND CONSUMPTION UNITS OF THE ENERGY SYSTEM NEED TO GET CHARACTERIZED AND CENTRAL OR DISTRIBUTED CONTROL WILL BE IMPOSED ON THEM. REAL TIME SYSTEM DESIGN PRINCIPLES ARE FOLLOWED. THE SCIENTIFIC INNOVATION IS THAT THERE IS A DEGREE OF FREEDOM IN THE DESIGN OF THE CONTROL THAT MAKES THE SYSTEM SELF-REGULATED. INTELLIGENT CONTROLLERS PERFORM DISTRIBUTED CONTROL OF THE CONSUMPTION. THE INTELLIGENT CONTROLLERS ARE EASILY INSTALLED BETWEEN THE GRID AND THE LOADS AND ACT INDEPENDENTLY WITHOUT REQUIRING NETWORKING. SIMULATION RESULTS SHOW THE BEHAVIOR OF THE SYSTEM, IN DIFFERENT SITUATIONS, UNDER THE INFLUENCE OF THE DISTRIBUTED CONTROL. IN CONCLUSION, THE DESIGN CONSIDERATIONS PRESENTED, CAN WARRANTY STABILITY AND PROPER POWER QUALITY WHILE MAXIMIZING THE USEFULNESS OF RES.

1. INTRODUCTION

FOR AN ISOLATED POWER NETWORK TO BE 100% RENEWABLE ENERGY SUFFICIENT, IT HAS TO UTILIZE DIFFERENT FORMS OF RENEWABLE ENERGY SOURCES (RES). WHEN ONLY ONE FORM OF RES IS USED AND THAT ONE CANNOT PRODUCE FOR A PERIOD OF TIME, THEN THE SYSTEM FAILS. WHEN DIFFERENT FORMS OF RES ARE USED THE SYSTEM IS CALLED HYBRID. THE PRODUCTION OF HYBRID ENERGY SYSTEMS CONSISTING OF DIFFERENT RES IS MORE BALANCED.

Isolated Renewable Energy Sources systems can be divided into two categories:
(a) Small scale, load-supply systems (i.e. single houses, signal repeaters etc.), consisting of one or more RES, energy storage and a compatible power generator unit such as a Diesel generator. If this is the case, the Energy Management System (EMS) is used to maximize the RES power generation, control the energy storage and schedule the Diesel generator operation and
(b) Medium scale systems, supplying small communities or small islands, where the EMS is responsible for power production management, control and scheduling of consumption and storage, by the use of load demand and RES power forecasting models. Usually large-scale systems do not exist in isolated networks.

Even well designed hybrid systems cannot match the production and storage with the demand of power without the use of an Energy Management System (EMS) that incorporates the requirements of the system and the characteristics of its consisting units. These EMS have to be designed to be partially self adjustable to counteract the fact that the installed consumption changes often.

THIS PAPER PRESENTS EXISTING WORK IN ENERGY MANAGEMENT FOR HYBRID SYSTEMS, TRIES TO FORMALIZE THE CHARACTERISTICS OF HYBRID RES POWER SYSTEMS COMPONENTS AND FINALLY PRESENTS A METHODOLOGY FOR EMS DESIGN THAT CONTROLS AND/OR MANAGES THE PRODUCTION, STORAGE AND CONSUMPTION UNITS WHILE WARRANTING SYSTEM STABILITY UP TO AN EXTEND.

2. HYBRID SYSTEM COMPONENTS AND THEIR CHARACTERISTICS

THE UNITS OF A HYBRID SYSTEM COULD BE DIVIDED INTO FOUR MAIN CATEGORIES, ACCORDING TO THEIR PRODUCTION-STORAGE-CONSUMPTION COMPONENTS:

A. ONLY-PRODUCTION UNIT
WIND GENERATORS (WG) (LESS PREDICTABLE)
PHOTOVOLTAIC PANELS (PV) (MORE PREDICTABLE)
SOLAR THERMAL PANEL (MORE PREDICTABLE)
ETC.

B. STORAGE AND PRODUCTION UNITS
BIOGAS (PREDICTABLE)
WATER TURBINE (PREDICTABLE)
ETC.

C. ONLY-STORAGE UNITS
BATTERY SYSTEMS (PREDICTABLE)

ICE STORAGE
(PREDICTABLE)
ETC.

D. ONLY-CONSUMPTION UNITS
BIG CENTRALLY CONTROLLED (FOR PUBLIC USE) (PREDICTABLE, SCHEDULED)
SMALL NOT CENTRALLY CONTROLLED (FOR PRIVATE USE) (LESS PREDICTABLE)

IT HAS TO BE NOTED, THAT THE STORAGE SYSTEMS, CONSUME ENERGY DURING THE STORING PHASE. FOR EXAMPLE THE WATER PUMPS OF A PUMP-STORAGE SYSTEM, THE COMPRESSOR OF THE WATER TO ICE TRANSFORM UNIT, THE BIOGAS TANK AIR PUMPING MOTORS CONSUME ENERGY WHEN IN STORING PHASE. THIS FUNCTION OF STORAGE SYSTEMS WILL BE CONSIDERED AS CONSUMPTION FOR THE EMS.

3. EMS DESIGN CONSIDERATIONS

THE EMS HAS TO :

- **MONITOR AND CONTROL THE PRODUCTION UNITS**
- **MONITOR AND CONTROL THE STORAGE UNITS**
- **MANAGE THE CONSUMPTION UNITS AND**
- **MONITOR THE POWER NETWORK TO ENSURE STABILITY AND PROPER POWER QUALITY.**

THE PROPOSED EMS USES PARTIALLY CENTRAL AND PARTIALLY DISTRIBUTED CONTROL:

A. CENTRAL CONTROL IS PROVIDED FOR THE PRODUCTION UNITS, THE STORAGE UNITS AND THE BIG CONSUMPTION UNITS. THIS PART IS CALLED CENTRAL EMS (CEMS). A COMPUTER SYSTEM HOSTS THE CONTROL PART OF THE CEMS.

b. For the rest of the consumer units, Automatic Distributed EMS (ADEMS) control is proposed. Central control of a big number of distributed loads (i.e. house appliances) would require a complex control system and network, resulting in increased cost and installation complexity.

Thus, a number of small inexpensive intelligent controllers perform the distributed control locally and also stabilize the power network operation. The functional characteristics of such a controller are presented in Section 3.2. Figure 1 illustrates the structure of an Energy System. The power "entering" the Distribution Network must be equal to the power "leaving" the Distribution Network, minus transmission losses.

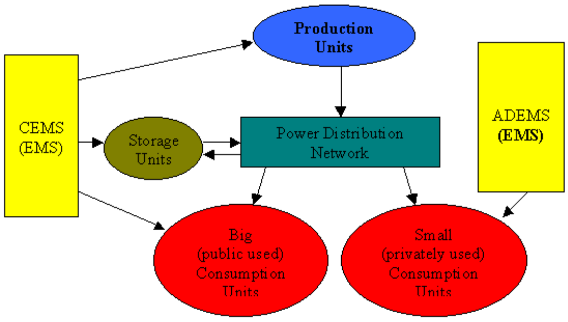

FIGURE 1. ENERGY SYSTEM WITH CEMS AND ADEMS CONTROL

3.1 CEMS

A Real Time System (RTS) that runs at the CEMS computer system performs the management of the production, storage and the big consumption units. A scheduler in the RTS does the scheduling of all consumption units of the CEMS. A lot of work has been done in this direction, in the design of real time operating systems for computers, where different resources have to be managed and shared by all processes requesting them. The CEMS must be designed for maximum performance.

Two samples of the many possible scenarios would be:

a. The production units are producing more than the current energy demand. Then the excess energy is stored. The CEMS controls in which storage(s) units the excess energy will be stored.

b. The production units are providing energy, while all storage units are totally full. The CEMS turns-on the big consumption units, if applicable.

3.2 ADEMS

The ADEMS consists of a number of Intelligent Controllers (IC), where each one automatically switches a load ON or OFF. Each IC continuously monitors the power grid characteristics and extracts information about the present and previous state of the power network, at the specific point of the network where the controller-load combination is connected. Based on this information and the specified importance of the controlled load, the IC takes one of the following actions for its load: to connect it, disconnect it, keep it connected, or keep it disconnected. Its decision is based on: (a) the voltage amplitude, (b) the frequency, (c) the history of the voltage signal over the last few minutes, (d) the importance (priority level) of the load, (e) the current state of the load (ON/OFF) and (f) the time interval in the same state. Such controllers have been designed and implemented inexpensively using microcontrollers. One IC has to be installed on each load and its importance (priority level) must be pre-adjusted. When the power grid is overloaded, the ICs of lower priority loads switch-off their loads. Thus, the power grid recovers, preventing instabilities, brownouts and blackouts, while at the same time the loads are protected from damage. When the power network is underloaded, even though the CEMS is acting the scenario 2 described above, then the ICs of the ADEMS will switch-on loads (the applicable ones).

The timing interval for acting of the CEMS and the ADEMS must be in accordance. When the network is overloaded (undervoltage case) the CEMS acts first and after a time interval the ADEMS reacts. This way, if the problem is not solved by the CEMS, the ADEMS action stabilizes the network. This is achieved by defining shorter action timeouts for the CEMS to switch-on power sources than for the ADEMS to cut out loads. The CEMS may not decide to switch-off important loads and in this case the ADEMS performs load shedding, thus reducing the power peak. When the power network is underloaded (overvoltage case, not instant, not extreme) the CEMS and ADEMS act independently. The CEMS turns-on all applicable consuming units, while the ADEMS turns-on all applicable consuming units, too.

A substantial number of ICs have to be installed to achieve distributed stabilization of the power network. Their low cost, together with the degree of protection they offer to the appliances and their ease of installation, makes them attractive for installation by many consumers, taking into account the substantially decreased possibility to be totally cut-off. When deployed on a large scale, they help the power network to recover faster and the critical (highest priority) loads can operate without shedding. The ICs help to improve the quality of electricity and the stability of the power network. Alternative methods to ADEMS, that can control a big number of loads, are for example the Power Line Carrier (PLC) or the one-way radio transmission communication techniques. The drawback of these techniques is that they require more installation and usage complexity (since they are actually centrally controlled), they cost more and they are not self-adjustable.

4. RESULTS AND CONCLUSIONS

Simulation results show the improved behavior of the system, under different production and load conditions, attributed to the distributed control. The design considerations presented, can warranty stability and proper power quality in an isolated energy system while maximizing the utilization of RES.

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