Intelligent Distributed Autonomous Electric Energy System for U.A.E.

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Abstract

IDAES is a network f a number of interconnected sub networks that has cell-like connections which can operate independently in case of failure. Each sub network has an adequate generating capacity to serve critical loads and to communicate internally among generation, loads and control devices. IDAES will ensure an uninterrupted supply of electricity to the more important loads to maintain the stability of the critical infrastructure.

Service disruptions and blackouts have emphasized the vulnerability of the critical electricity infrastructure. The decrease in availability and integrity of the electrical infrastructure is due to the trends going on in the industry, where electricity is considered as a marketable product rather than a service, on top of the fact that power infrastructure in developing countries is approaching its final years of service.

1. Introduction

New sustainable sources of energy are the keys for the future better life. They can also help to improve the reliability of the existing power electric system. A feasible solution to low reliability problem in power systems could be an Intelligent Distributed Autonomous Electric Energy System or IDAES. An IDAES is a network of some interconnected sub networks that has cell like connections which can operate independently in case of failure. The IDAES micro grid aims at intelligently managing customer-owned distributed energy resources such that these assets can be shared in an autonomous grid both during normal and outage operations. The proposed concept is expected to make significant contributions during emergency conditions, as well as creating a new market for electricity transaction among customers [1].

2. IDAES

The IDAES concept ensures an uninterrupted supply of electricity to the high priority loads, thus maintaining the integrity of the critical infrastructure. This paper defines the concept, components and architecture of IDAES, and demonstrates how the electronic control concept can be applied [2]. The proposed concept takes into account the availability of cleaner, more efficient and cost-effective small-scale generation sources, as well as advanced IP-based communication technologies in building a resilient electric power system with demand-side participation. Advanced concepts for intelligent adaptive power grids with distributed intelligence is a longer term objective of Intelligent Distributed micro grids [3]. The near-term objective is the modeling and analysis of advanced concepts for integration of Distributed Generation energy resources and Intelligent Sensing Agents in micro grids within a defined regional electric distribution system, or Target micro grid. The emphasis is placed on the Distributed Generation and distributed sensing strategies, particularly Intelligent Sensing Agents in an overall framework of Intelligent Distributed micro grids [4]. Each sub network has an adequate generating capacity to serve critical loads and to communicate internally among generation, loads and control devices. IDAES will ensure an uninterrupted supply of electricity to the more important loads to maintain the stability of the critical infrastructure. Service disruptions and blackouts have emphasized the vulnerability of the critical electricity infrastructure. The decrease in availability and integrity of the electrical infrastructure is due to the trends going on in the industry, where electricity is considered as a marketable product rather than a service, on top of the fact that power infrastructure in developing countries is approaching its final years of service [4].

3. Conventional Power Systems

The conventional power system consisted mainly of a central station generating plant supplying electricity through transmission lines and then to distribution networks to end users. This practice compromises delivering steady and uninterrupted power supply to critical loads. This is due to the fact that distribution networks depend entirely on electricity coming from the grid without internal generation to support the critical loads in case of outage. Applying the deregulation policies, there are no utility owned power distribution feeders and only a few customer owned generators. This results in making critical loads more vulnerable to disturbances and outages in power systems. The objective of IDAES is to secure all critical loads located in the Autonomous Power Systems (APS) during outages. To achieve the objective, a distributed generation (DG) unit such as solar photovoltaic systems, diesel engines, fuel cells or electric vehicles must be places in each distribution circuit if no existing back up generation exists. This gives the APS the capability to be independent so they can fulfill their responsibility toward the critical loads and operate without the help from the central grid in case of its failure. Along with the necessary generation capacity a support from technologies in sensing, metering, communicating and controlling the operation of these elements must be known for the IDAES to succeed.

4. Minimizing LOLP

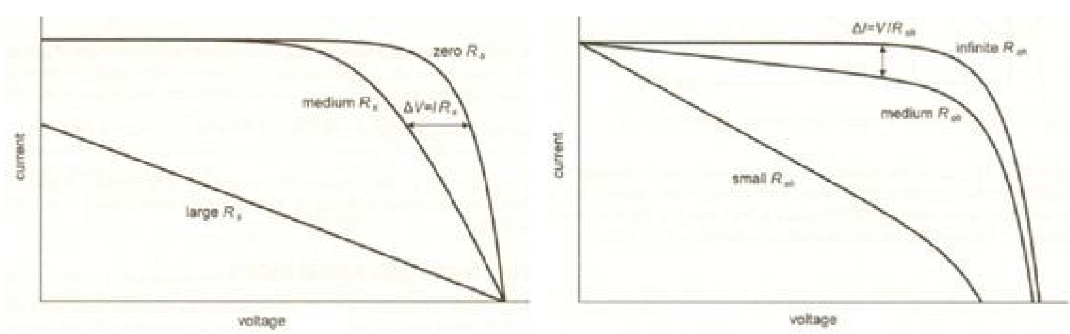
To meet the objective of IDAES, an optimization model is used to minimize the total annual capital and operating costs of the generators. The model uses the popular index of electric power systems called Loss of Load Probability (LOLP), which is defined as the fraction of time in which the available capacity is insufficient to serve the hourly demand. The variables that will lead to make a decision are the sizes of distributed generating units in KW that will be installed in the system. The capital and operating expenditures will be minimized to such a value that will compromise the delivery of an uninterruptable power supply to the critical loads. In power systems the norm of data communication has been the supervisory control and data acquisition (SCADA) system. In case of IDAES, each APS will have its own SCADA facility and the multi agent concept that operates on an IP network. An agent is a software based unit that can sense and respond to changes in signals to accomplish its individual goal.

5. IDEAS for U.A.E.

The U.A.E. has a big potential to generate solar electric energy. Forecasts suggest that by 2030, up to one third of the U.A.E.'s required energy will come from renewable sources. Solar energy, the cleanest source in environmental terms, is likely to form a large percentage. The U.A.E. can afford to take this route as it receives more than 300 days of sunshine in a year. Photovoltaic cells are the most common device to harvest solar energy and convert it to electric energy. A solar cell may operate over a wide range of voltages (V) and currents (I). By increasing the resistive load on an irradiated cell continuously from zero (a short circuit) to a very high value (an open circuit) one can determine the maximum-power point, the point that maximizes V×I, that is, the load for which the cell can deliver maximum electrical power at that level of irradiation. The maximum power point of a photovoltaic varies with incident illumination. This information is used to dynamically adjust the load so the maximum power is always transferred, regardless of the variation in lighting. An important term describing the overall behavior of a solar cell is the fill factor (FF). It is a measure of the junction quality of the cells and series resistance. This is the ratio of the maximum power point divided by the open circuit voltage (V_{oc}) and the short circuit current (I_{sc}):

$$FF = \frac{V_{mp} * I_{mp}}{V_{oc} * I_{sc}} \tag{1}$$

Thus, the nearer the fill factor to unity, the higher the quality of the module. Commercial Si PV modules should have FF range from 0.6 to 0.8 with FF falling after field exposure. Large fill factor is related to small series resistance- R_S and large shunt resistance R_{sh}, both are voltage independent (Figure 1).



a) Series resistance a) Shunt resistance

Figure 1. Effects of the series resistance and shunt resistance on the fill factor.

The characteristic resistance, R_{ch}, is the ratio of Voc to Isc:

$$R_{ch} = \frac{V_{oc}}{I_{sc}} \tag{2}$$

$$FF \approx FF_0(1-\frac{R_s}{R_{ch}})$$
$$or \tag{3}$$
$$FF \approx FF_0(1-\frac{R_{ch}}{R_{sh}})$$

where FF_0 is the fill factor when R_s is zero or R_{sh} is infinite. Since the fill factor determines the output of the module, the maximum power is then related to both series and shunt resistances. These parasitic resistances are detrimental to solar cell performance because they reduce the device power output. A low fill factor represents a large series resistance and a low shunt resistance. By comparing the four characteristics shown in Figure 1 we can see that this will definitely lead to a low maximum power. Normally, for commercial cells, Rs is designed to be approximately inversely proportional to the rated short circuit current, so that the percentage power loss in Rs, is approximately constant with cell (about 2.5 %):

$$R_s \approx \frac{1}{40 I_{sc}} \tag{4}$$

Thus for n series cells in a module the total series resistance is the product of n and R_s. This model can help the designer to estimate the output power available in the system. Electricity is on the only form of energy obtained from solar energy. Other usage of solar energy is running a desalination plant by solar energy. Solar energy can also be used for water desalination. Figure 2 shows a desalination model that can be energized by solar energy.

U.A.E. residents can be part of IDEAS and contribute power to the network and vise versa. A proposed architecture of cooperation among residents and the U.A.E. power utilities can consist of the interface layer, the agent layer and the inner most layer, the Local Area Network (LAN). The interface layer connects all data sources, data storage units and data users to their associated agents. Via the interface layer the user will have the ability to sense price signals from the utility and access real-time information on available generation and load requirements. After the interface layer comes the agent layer which consists of multiple agents that are interconnected through LAN. The agents connect all elements, specifically, the APS and consolidating information to protect critical loads when the grid fails. The information collected by the agents from all generators, loads and devices are: ID, Location, Size of power, Type of power, Status, Performance and proposed Price. The Data analysis and IDAES management agents use the mentioned information to build an instantaneous optimum dispatch scheme. Then a signal is sent to control agents to change the state to a more efficient optimum state. The application of a multi-agent structure will support the IDAES to fulfill its goals, e.g. secure critical loads during faults and employ demand side management during normal operating conditions. When a device agent senses a failure in the electric power system from the abnormal status of a device in the APS, the device agent sends a signal to the data analysis agent. The data analysis gathers information from DG agents, load agents, and device agents to check the availability of generation and load requirement. Then the IDAES management agent calculates the optimum dispatch form to ensure availability of electricity to the high priority loads such hospitals or loads with high outage costs and restores them. Finally, the agents dispatch their associated elements by starting standby generators or shed any unnecessary low priority load. To achieve demand management when a user console senses a high price signal from the grid, the customer may want to reduce the loads to avoid high charges. The data analysis agent requests information from DG agents, load agents and device agents to check the availability of standby generation, loads and operating costs of all available DGs. The analysis agent sends the information to the IDAES management agent, which instructs the internal generation unit to produce necessary generation requirement and sell electricity back to the grid.

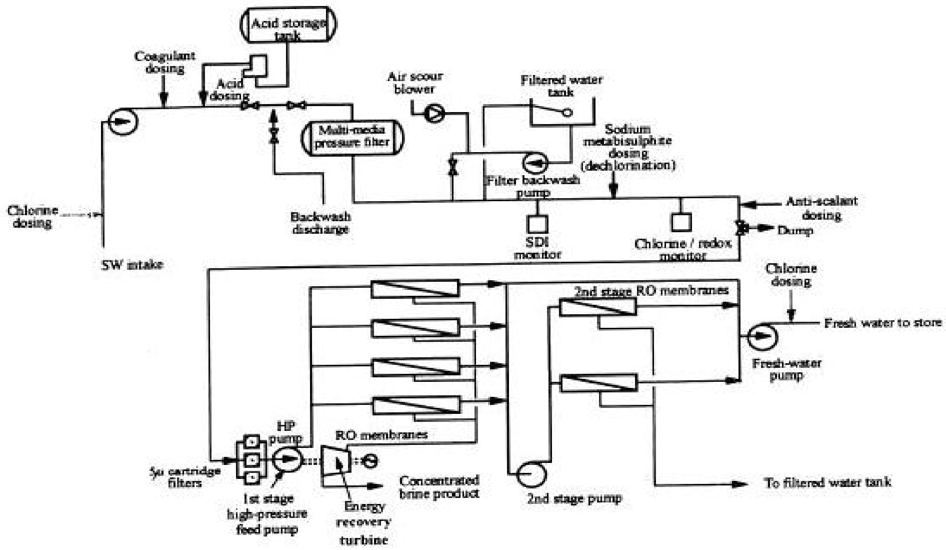


Figure 2. Desalination model energized by solar energy.

6. Conclusions

IDAES is a feasible future power grid for U.A.E. as the demand for electricity is increasing. It can help the generation of energy in U.A.E. by optimizing the usage of all sources of energy. It will mange and control the energy coming from different sources. It will improve the reliability of the electric network and prevents unwanted blackouts. It will also reduce the pollution and help the environment.

7. References

[1] S. Rahman, M. Pipattanasomporn and Y. Teklu, "Intelligent Distributed Autonomous Power Systems (IDAPS)," in *Power Engineering Society General Meeting, 2007 IEEE,* 24-28 June 2007, pp. 1 – 8.

[2] S. Rahman and M. Pipattanasomporn, "Intelligent Distributed Autonomous Power Systems (IDAPS) and their impact on critical electrical loads," in *Critical Infrastructure Protection, First IEEE International Workshop,* 3-4 November 2005, pp. 1- 9.

[3] S. Rahman, "**Framework for a resilient and environment-friendly microgrid with demand-side participation," in** *Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE,* 20-24 July 2008, p. 1.

[4] D. Cox and T. Davis, "Distributed Generation and Sensing for Intelligent Distributed Microgrids," in *Proceedings of the 2006 IEEE/SMC International Conference on System of Systems Engineering, Los Angeles*, CA, USA, April 2006, pp. 1 – 5.

Author Biographies

Mr. Mohamed Ghazi Balfaqih was born in Abu Dhabi, U.A.E. and received his B.Sc with Honors in Electrical Engineering from the Petroleum Institute in 2006. He is currently pursuing a Masters of Engineering in Electrical Engineering at the Institute. He worked for two years as an Electrical Engineer in the Engineering & Major Projects Division of Abu Dhabi Company for Onshore Oil Operations (ADCO). He was awarded the fastest graduate to be declared operational in Abu Dhabi Company for Onshore Oil Operations in 2007. His research interests are power system analysis and power system operation and protection.

Dr. Majid Poshtan was born in Tehran, Iran and received his B.S.in Electrical Engineering from Tehran University, Tehran, Iran, in 1988, the M.S. degree in Electrical Engineering from the University of New Brunswick, Fredericton, NB, Canada, in 1992 and the Ph.D. degree in Electrical Engineering from Tulane University, New Orleans, LA, U.S.A., in 2000. He is currently an Assistant Professor in the Department of Electrical Engineering, The Petroleum Institute, Abu Dhabi, U.A.E. Before joining the Institute, Dr. Poshtan has worked in different electric power projects in Entergy Corp, U.S.A. His research interests include power system analysis, power system protection and power quality studies. Dr. Poshtan received the IEEE Region 5 graduate paper contest Award in 1998 and 1999, and he is also the recipient of The Petroleum Institute outstanding faculty award in 2005. Dr. Poshtan is an active member of IEEE and is serving as the Petroleum Institute IEEE student branch advisor.