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Implementation of Smart Grid Decision Support Systems

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ABSTRACT

An information system known as Decision Support System (DSS) is on the basis of computer interaction to support the making of decisions in planning, operations for usage of power, management, organization and business. Decision making is dynamic and the rapid changes cannot be identified easily but can have assistance from computer and communication technologies by the compilation of information obtained over a wide range of resources such as raw data, the knowledge and experience of the experts and documents. The initial concept of the decision support originated from a decision making abstract study at the Carnegie Institute of Technology and Technical Practice. This was on the basis of computer system interaction at Massachusetts Institute of Technology in the 1960s. Around the 70s, decision support began to expand in academia and around that time, the first paper featured in a journal and at a conference. The Chinese introduced the DSSs in the 80s. The applications of the DSS in the early 90s had broaden into various areas via warehousing of data and online DSS applications are spread into different areas through data warehousing and online logical processes. Of late, with the evolving of cloud computing technology, DSS on the basis of cloud computing technology was suggested. Ever since the development of DSS over the last 30 years or so, there are at least 20 techniques of implementing the decision support system. It is hard to differentiate which one is the best principal for solving decision making challenges because for the most part, the suggested DSS are project-oriented. There is a lot of technical aspects in which DSS has been involved such as electricity, transport and many others like dispatch of resources. A lot of advanced technologies, creative architectures, and paperback algorithms have been deployed into the existing electrical power systems for improved energy efficiency and accomplish resource allocation optimization and ultimately make the grid "smart".The smart grid implementation is a gradual process to substitute the conventional power systems' elements built on the basis of existing systems and building brand new systems which would be very costly. Smart grid planning involves not only the consideration of these creative technologies but also respecting the interest of all the stakeholders involved. Decision making requires to be executed to analyze each smart grid component and its cost before investment and consequently deploying into the real grid.

Keywords: Implementation of Smart Grid Decision Support Systems

INTRODUCTION

The IEEE in 2004 released a guide on the indices of electrical power distribution reliabilities used for the planning and operation of the power system. The DSS is needed to assist organizations and governments or planners of the network to make crucial decisions in the event of a real project. The most important elements of decision support systems in power systems is reliability, planning and security.

Requirements for a Decision Support System

A standard Decision Support System includes various scientific aspects such as technologies of simulation, computer science, software programming and perceptive science and so on. There are three kinds of problems associated with decision making and these are structured, unstructured and semi-structured. For structured, the issues can be resolved using standard solution methods by clearly stating the procedures for making a making a decision. There are no specified challenges in the unstructured and the decision procedures are followed one time only. Optimization in semi-structured problems is not guaranteed in as much as the decision making procedures are specified. The DSS is different depending on the level of the business companies and organizations. Three distinctive levels are involved in organizations. Firstly, there is strategic planning, which includes long term policy planning, which is used for governing the acquisition of resources, usage and disposition. Then secondly, the management control makes sure that the resources are acquired and optimized in order to accomplish the objectives of the organization. And lastly, operation control makes sure that there is progress.

Functionalities of the DSS

Generally, as earlier mentioned, the DSS is project-oriented and its functionality is determined by the architecture of the system. Using various architectures, the functionalities of the DSS are summarized as follows:

- Obtaining, management and providing the organization with exterior information associated with decision questions in areas such as policy, technology, market, economy, society and environment.
- Obtaining, management and giving the organization intramural information associated with decision questions in areas such as the capabilities of production, order requests, storage status and the finance.
- Obtaining, management and giving feedback of each option of decision performance like processing of contracts, plan for supplying material and implementing the production.
- Has the capacity to store data and manage mathematical models closely linked to decision making.
- Has the capacity to store and provide frequent usage of mathematical methodologies and algorithms such as linear programming, regression analysis and models of computational intelligence
- Has the capacity to aggregate and modify data easily including modeling and algorithms.
- Has a flexible way of gathering, processing, forecasting and analyzing data through representation and methodologies.
- Provides a platform for interaction between man and machine as well as the graphic output functionality. Also, there is capacity to meet the request of random probability distribution of data queries to give answers to questions such as "what...if..." and so on.
- Gives a platform for data communication so that the data required can be gathered, processed and transferred to the user in time.

A typical architecture of the DSS must have an optimization toolbox, a data mining toolbox, an online analytical toolbox, a system for processing transactions as well as a database as demonstrated in the fig. 1 to add all the functionalities above. Users can produce problems to the DSS and get the analyzed answers from the user platform. The data mining toolbox can locate the necessary data from a large database in which the data associated to that problem is located.

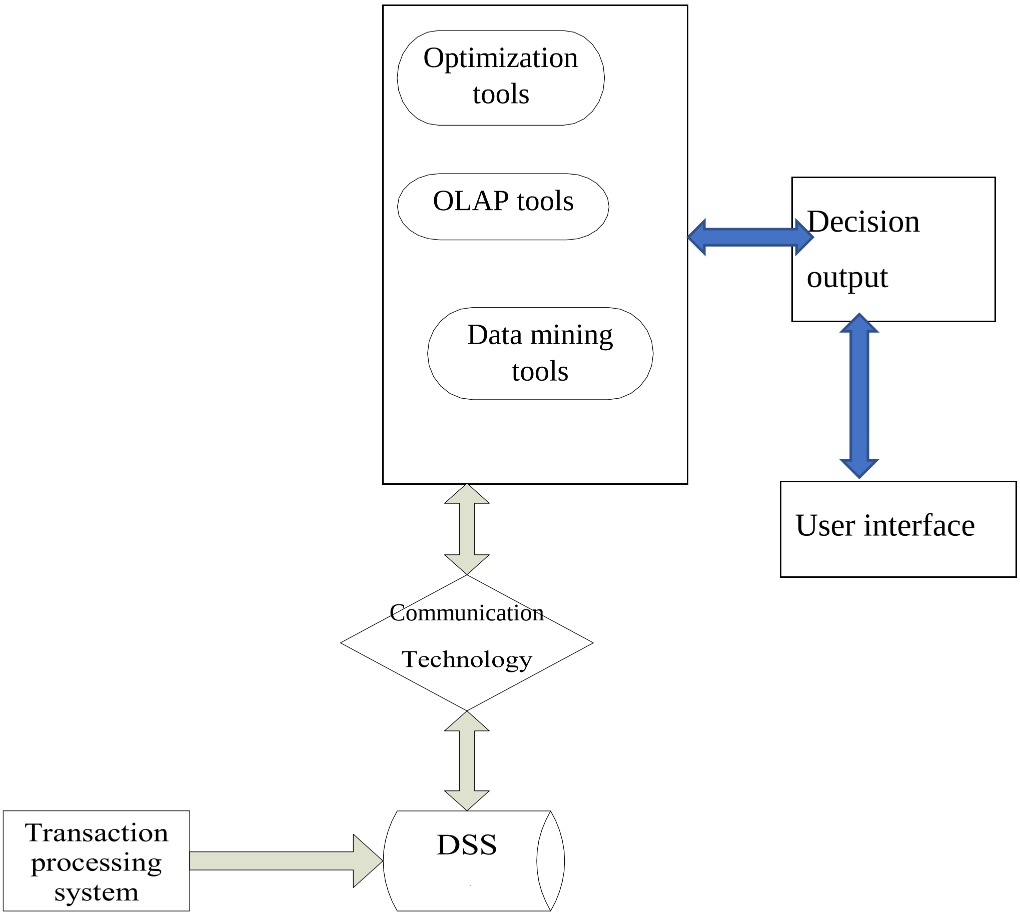

Figure 1: A typical structure of DSS

DSS Requirements

There are basically five kinds of DSSs to accomplish decision making and these are data driven decision support system, communication driven decision support system, knowledge driven decision support system, model driven decision support system and document driven support system (Dr. Saeed Shiry, "Decision Support Systems", n.d.). There are some generic needs regardless of which type of DSS used for a particular project. Some of them have been listed below; It has to be compatible with as many processes of decision making and structures as possible. Should have an interactive platform that is user friendly. The users can have access and be able to control it. Enable the end users to come up with a DSS without challenges. Must be able to support modification, access of data and analysis. Should be able to operate in both standalone and web based situations. DSS has been applied in many areas, such as port planning, workload planning, oil refineries, traffic control and safety of drivers including helicopter landing.

Scenarios for Power System Stability

The power system is characterized by a lot of variables and uncertainty. A lot of countries are studying wind and solar energy penetration into the power system in order to accomplish a percent generation high enough for the reduction of carbon emission and pollution of air. Integration of other energy resources such as wind turbines and Photovoltaics (PV) farms could bring instability into the power grid. The level of penetration of the power system is closely associated with the flexibility of generation capacity installed in the network. To handle issues of ceasing and beginning again that come with solar and wind energy generation due to changes in the weather, the generators should have the ability of quick response. Different scenarios have to be examined to illustrate the potentiality of optimizing different renewables. To develop a full scale project, it is necessary to conduct a benefit-cost analysis. However, in regards to technology, there is still a lot of challenges and there is still room for other engineers to make their contributions. Furthermore on the scenarios of renewable connection, strategies for load shedding, hinder the power system frequency instability on the basis of real time data from frequency relays. Power systems loads vary with time and for this reason, strategies for load shedding are having challenges sufficiently and precisely take actions for shedding. On the side generation, there is an increasing in non-dispatchable and obstinate renewable energy generations that are being integrated into the system bring complications for generation predictions and ultimately causing recurring power imbalance. In the event where the load shedding is not working properly, the whole grid becomes vulnerable to situations that could be dangerous due to the fact that the frequency value will drop to levels that will destroy the generators. Consequently blackouts are next. Therefore, a model with the penetration of renewable energy has been suggested in order to assess scenarios for stability.

Investigation on Renewable and Solar Penetration

Renewable energy resources such as wind, solar and hydro are the best possible solutions in regards to the reduction in the emissions of carbon under the pressure increased power demand. Global warming is caused by the power plants that burn fossil fuels for the generation of electrical energy. Such fossil fuels include, coal, natural gas and oil. It is now a trend to advance renewable energy resources to replace fossil fuels. However, the challenge with renewable energy resources is that they are intermittent and cannot be forecast accurately. Countries across the globe have diverted their attention towards generating renewable energy for decades now. The European Wind Energy Association has a target that by 2030, 23% of electric power should be generated from wind [1]. Denmark hit the 20% mark in 2006 of wind generation and it was suggested that they set the target to 50% by the year 2030. Spain had set their wind penetration target to 15% in 2011, of which it equaled to 20GW installed capacity. The level of penetration of renewable energy resources into the power system is dependent on the structure of generation. Power systems with large traditional generation power plants like coal and nuclear plants cannot respond very well with energies that have intermittent characteristics. Networks based on hydro-power generation and pumped hydro energy storage responds very fast to differing wind energy [2]. In May of 2010, a penetration study on solar and wind incorporation was conducted by General Electric (GE) Energy via the United States National Renewable Energy Laboratory (NREL). A review is concluded on the various scenarios solar and wind penetration from 10%-30% for wind energy and from 1%-5% for solar energy [3]. Research presents a large time scale for a one day long for unit allegiance and a minimum time scale for regulation of minute to minute. The forecasting errors exist due to the fact that the weather is changing from time to time thus makes renewable energy unreliable. All elements in the power system such as loads, power lines and generators are variable and are have uncertainties [4]. Even traditional electrical power plant such as nuclear and coal fire plants suffer from variability and uncertainty. The case study by Ernest Orlando Lawrence Berkeley National Laboratory [4], the integration of large wind farms can help to smoothen the output power in as much as renewable energy is variable and there is uncertainty. The same is true for load aggregation that can smoothen the load curve. The study of power quality as well as constant changes brought about due to uncertainties and variabilities is essential for the study of stability.

Conversion of Wind Energy

Generally, power performance of the wind turbine with no dimension can be represented in two ways. Power coefficient Cp is used for fixed speed of wind with a tip speed ratio λ. Ratio J represents the angular speed of the rotor and the power coefficient Kp represents the rotor speed. To make things easier, I have adopted the first approach in this project for a wind turbine of performance coefficient Cp, wind speed vwind, air density ρ and turbine swept area A. In order to achieve the maximum value of the power output, it is required to operate the wind turbine at maximum power coefficient Cp, determined by λ the tip speed ratio and by β the blade pitch ratio. The maximum power coefficient is only possible when the blade pitch angle β is 0. Figure 2 shows the relationship between the power coefficient Cp and the tip speed ratio λ when β equals to 0 below, and the parameters are obtained from Matlab Help, Distributed Resources (DR) and wind turbine.

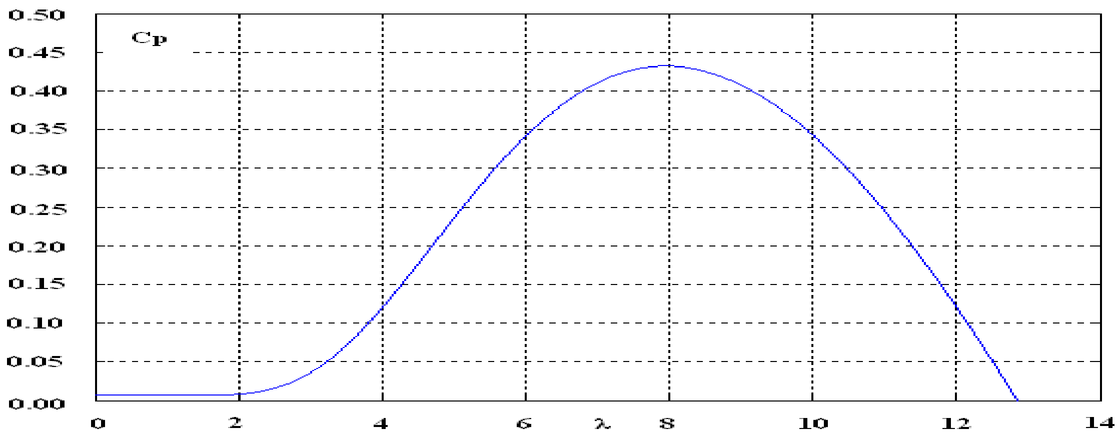

Figure 2: Rotor power coefficient performance Cp against tip speed ratio λ

Generally, when the wind turbine is starting, there is a cut in the wind speed. Basically, there is power generated from wind if the wind speed is less than 5m/s. While in operation, there is a relationship between the power generated and cube of the wind speed. When the generator reaches its rated power, the power output is kept constant in as much as the there is an increase in the wind speed. In the event where the wind speeds exceeds 25m/s, the wind generators are shut down because at this level the wind is too strong and can cause damages [5]. Figure 3 below demonstrates the changes in the output power with the variations in wind speed.

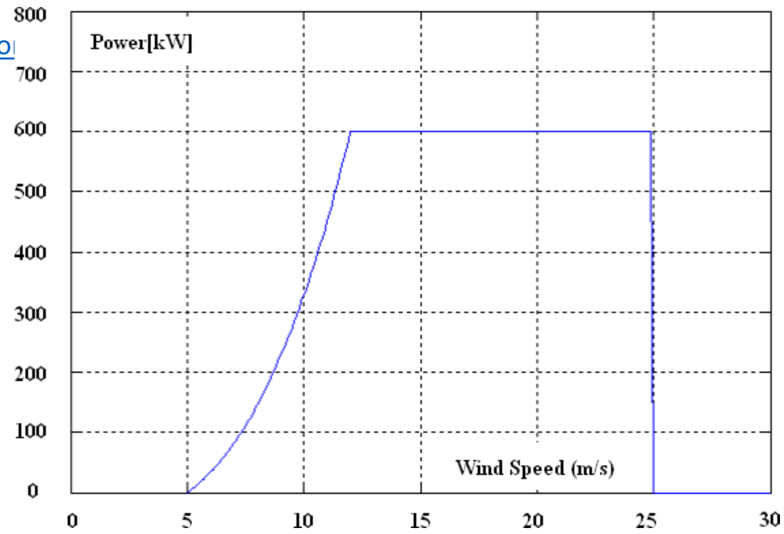

Fig. 3: Wind speed VS output power curve

Solar Energy Conversion

Output power from a collection of solar panels known as the solar array depends on how much radiation that is being injected to the array by the sun. The injection of radiant energy is not only affected by the height of the sun but also the radiation is not constant due to the passing of the clouds. Figure 4 shows the radiation of Westminster, London over a period of 24 hours. The figure clearly shows that there is a dramatic change within a short period of time. However, as earlier mentioned, the output can be smoothened by aggregation in the sense that that solar power has to be distributed in different areas.

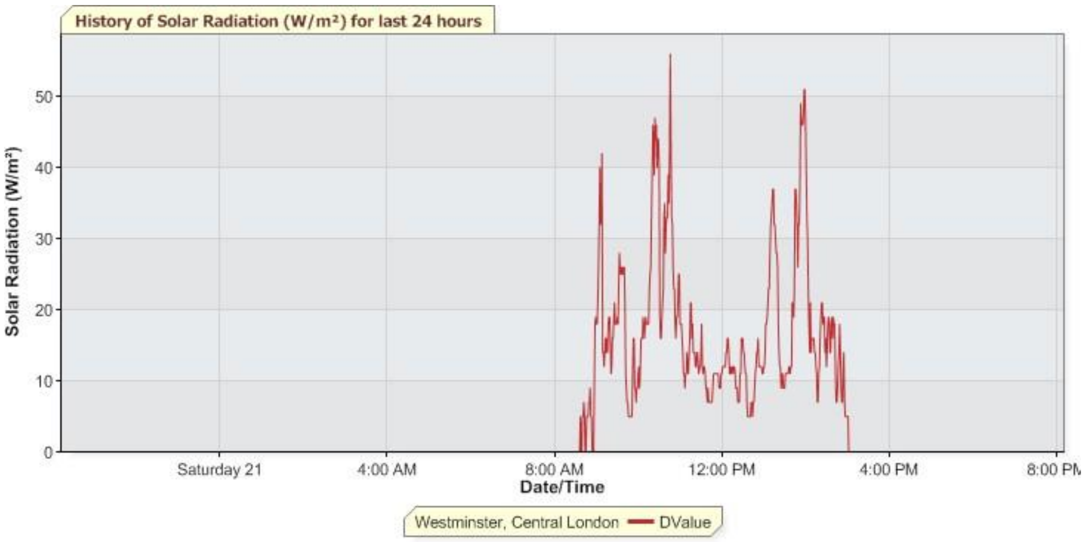

Fig. 4: Solar radiation for day-time with cloud impact

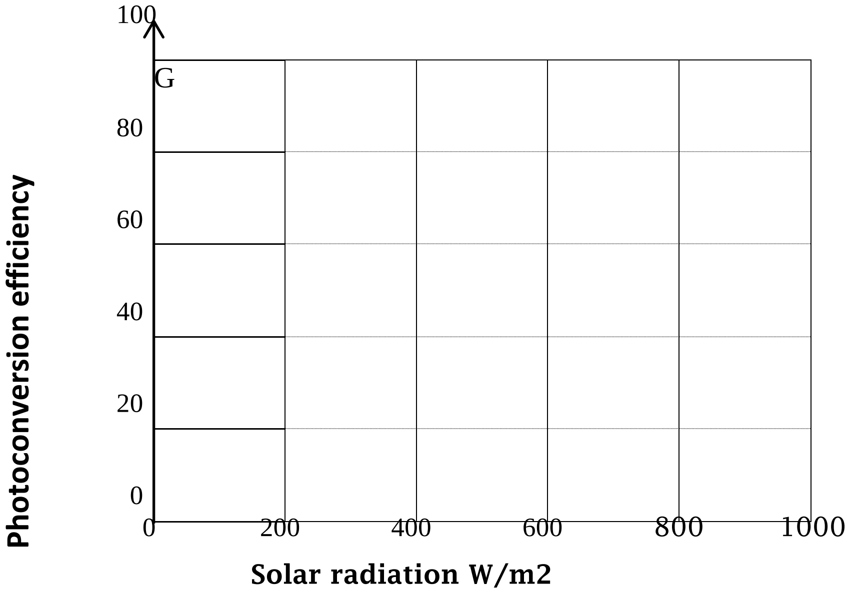

Fig. 5: Photo conversion efficiency VS solar radiation [6]

Fig. 6 provides information on the PV characteristics on the efficiency conversion during changes of the solar radiation. 500w/m^2 represents the solar radiation on a cloudy weather and 1000w/m^2 when the weather is brilliant. However, the PV conversion efficiency does not change very much [6].

Reliability Indices

There are three major driving factors influencing the development of the electrical industry and the increase in renewable energy and these are policies of the government, growing economies and security aspect for energy. Wind energy is still on the implementation stage and is on a more advanced stage than most technologies such as PVs and wave energy in regards to renewables [7]. The reliability of distribution networks and the adequacy in generation has attracted a number of countries in technical and economic aspects where investment in power systems is concerned. Renewable energy investments and any other elements of the power system need consideration when conducting a cost benefit analysis or policy making. Reliability evaluation is considered in a framework to create a common spatial picture to encompass renewable energy investments [8,9,10]. In other words, system reliability evaluation always targets at a single technical area that does not influence investors and or system operators on making clear decisions on the network planning but rather consider all the technological areas on system reliability as a whole. So far, there has not been a comparison between wind energy, distributed generation or centralized generation as far as system reliability is concerned.

CONCLUSION

A lot of advanced technologies, creative architectures, and paperback algorithms have been deployed into the existing electrical power systems for improved energy efficiency and accomplish resource allocation optimization and ultimately make the grid “smart”.

The smart grid implementation is a gradual process to substitute the conventional power systems’ elements built on the basis of existing systems and building brand new systems which would be very costly. Smart grid planning involves not only the consideration of these creative technologies but also respecting the interest of all the stakeholders involved. Decision making requires to be executed to analyze each smart grid component and its cost before investment and consequently deploying into the real grid.

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