STUDY OF USING SOLAR ENERGY SYSTEM TO SUPPLY A DATA CENTER

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Abstract - *Supplying the electrical energy of a data center is an important issue that plays a major role in design, reliability and operation of the data center. IT and data center industries will make very significant improvements over the next few years which indicates an ever growing demand of energy for data centers which can contribute to more consumption of resources and more generation of carbon. More and more, data centers are being asked not only to pay greater attention to their energy consumption, but also to consider and understand their relationship to the greater environment such as exploiting renewable energy. It implies that it is no longer just about how energy is used, but also about how it is produced. In order to use renewable energy as a power supply, its conformation to requirements of a data center should be considered, which are desired reliability and power quality. In this paper solar energy is investigated if it can meet the requirements of data center power supply.*

Key Words: Solar Cell, Data Center Power Supply, Renewable Energy, Energy Demand, Solar Energy

1. INTRODUCTION

Providing the electrical energy needed for operation of the data center is an ingenious and important approach. Electrical system of the data center includes transformer, generator, panel board, UPS and etc., and it can have different layouts and configurations. It plays an important role in determination of reliability of the data center and also affects the total cost of operation. If the harmonics ignored properly, the grid connection can affect the power market price [1]. They also can behave differently in islanding detection in case of using synchronous generators is the grid connected system [2].

Nowadays the growing developments of data centers along with other recent technologies such as plug-in electric vehicles are imposing constantly increasing in demand of energy to power plants [3]-[8], considering the limitations of fossil fuels such as the terminable sources used to generate the electricity and the pollution caused by generation of electricity from fossil fuels, the necessity of finding alternative source of energy gains a great importance and IT industries are more convinced to exploit other sources of energy, called renewable energy. In order to achieve this goal different sources of energy, other than fossil fuel exist.

Solar energy, in the form of radiant light and heat from the sun, has been harnessed and utilized by humans in different ways using a range of ever-evolving technologies. Solar radiation is considered as an available renewable energy on earth. To harvest the solar energy, the most common way is to use solar panels. The tilt angle of the solar panels plays an essential rule in capturing maximum solar radiation. Akhlaghi et al. [9] studied the sufficient number of optimal tilt angle adjustment to maximize residential solar panels yield. Every day earth receives a great and considerable amount of energy, the amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's nonrenewable resources but only small portion of this energy can be utilized. Developing accurate models can effectively predict the availability of solar energy based on weather forecasting [10]. In [11], a linear parameter varying model is developed that is capable of the taking uncertainties into account especially in climate related data. No need to mention that, solar cells are subjected to severe weather conditions and impact by foreign objects. Khalili et al. [12-13] introduced a wave propagation based health monitoring method using WSFE-based UEL which has a great potential to be employed in order to detect and localize any possible damage in solar cells and panels. Meshless methods such as peridynamics [14-15] can also be used in health monitoring of solar systems.

Solar power is obtained when the sunlight is converted into electricity. It can be done, either directly using photovoltaics (PV), or indirectly using concentrated solar power (CSP). Solar energy is not available at night, and energy storage is an important issue in order to provide the continuous availability of energy. Because modern energy systems usually assume continuous availability of energy, especially for a data center, solar energy must be stored in different forms. Gharghabi et al. [16-18] investigated the effect of the various contingencies to happen on the structure of a data center.

Since solar energy is not a permanent source of energy, and providing a continuing and constant energy for a data center is vital and indispensable, another reliable source of energy is definitely needed. In this paper, the power grid is considered to operate as a secondary source of energy, thus it guarantees that energy is always delivered to the data center, when the solar energy is not available for any reason.

Although solar energy has been substantially overlooked for years because of its unsecure and intermittent nature, the current climate concerns and energy crisis urge governments and academia to dedicate a large body of research and investigation to enhancing solar energy systems efficiency and reliability while these systems are getting widespread applications in both industrial and residential scales. One of the most important energy consumers in industrial sector are refrigeration systems. S. Aghniaey [19] in her paper analysed a solar-powered, ammonia-water refrigeration cycle that is able to provide temperatures as low as -40° C while using solar energy as the power source. In another paper [20] she compared this novel system with a conventional refrigeration system and a 12% increase in efficiency and 6% increase in COP was reported for the novel solar-powered refrigeration system. Solar systems are promising tools in cutting carbon footprint and reducing electricity demand and consumption in the near future.

The objective of this paper is to study the combination of the solar energy alongside the power grid to supply a data center. In this paper, the considerations of the power supply of a data center such as reliability and power continuity are investigated. The radiation graph of sun in Tehran is taken into account in simulations and the intermittent behaviour of the solar energy is examined. The load model of the data center is also implemented to present the variation of the energy it needs. By modelling and implementing the power supply system of the data center in MATLAB Simulink, the variation of battery state of charge and output power of each power provider are shown and investigated. The simulation shows the operations of the system for a week, when the solar cells are starting to charge the batteries. In order to increase the reliability of the system two batteries are used. Finally it is investigated that solar energy alongside the power grid can supply the data center.

2. BASIC WORKING PRINCIPLE

Figure 1 shows a schematic of the system with solar panel.

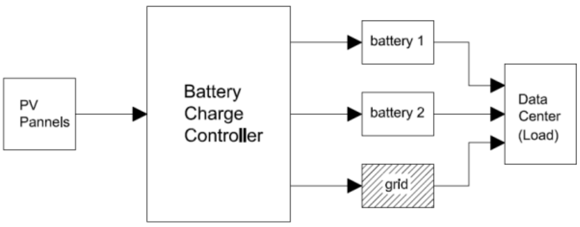


Fig. 1: Block diagram of the system

In this paper modeling of a grid connected solar cell system is used to present power supply stability. The model in Eq.1 is presented in [21] describes electrical characteristics of a solar cell.

$$I_{PV} = N_P I_{SC}\left(\frac{I_r}{100}\right) - N_P I_o\left[\exp\left(\frac{qV_{PV}}{nkTN_S}\right) - 1\right] \quad (1)$$

In which I_r is irradiance; T is junction temperature; I_O is saturation current; q is elementary charge of an electron; n is an ideality factor; k is Boltzmann's constant; N_p is the number of cells in parallel and Ns is the number of cells in series.

By increase of irradiance the output power will increase. But as it is presented higher temperature results lower output power and vice versa. So as a result a place with good irradiance and low temperature will boost the efficiency.

There are different methods used for controlling the solar panels. Maximum Power Point Tracker (MPPT) is a method that holds the output power of the PV panels, rather constant. Low cost MPPTs are designed to control the PV panels to operate off-grid. For example MPPT model presented in [22] does not need any external control signal to determine the working point. In [23] a robust three phase model for MPPT in PV panels connected to the grid is presented which by using MPPT and a current controller regulates the current. This model prevents the current overshoot. But in this paper in order to control the PV panels the controller or MPPT is not used, so that the effect of the variation of the sunlight in day on the constant load can be illustrated and also power continuity in a data center during the day can be demonstrated.

Charge controller manages the charging and discharging process of batteries. In fact it determines when a battery must be charging or discharging over the load in order to provide the power. For example in [24] a charge controller for lead acid batteries by using PWM in PI algorithm for standalone system is proposed. An improper algorithm of charge controller can harm the lead acid batteries. Scrutinizing the charge controller and analyzing it, is not the objective of this paper.

In [25] by developing an intelligent charge controller manufactured by Thompson microcontroller, the efficiency is increased by using a Microcontroller. The charge controller used in this paper is an intelligent charge controller which is capable of programming and sending controlling signals to start and stop, charging and discharging of batteries and power grid. The logic statements used for charge controller are as follows:

$$\begin{aligned}
&(a)\,Chg1 = (Bat1 \le 99).\overline{Dis1}\\
&(b)\,Chg2 = (Bat2 \le 99).\overline{Chg1}.\overline{Dis2}\\
&(c)\,ChGd = \overline{Chg1}.\overline{Chg2}.\overline{DsGd}\\
&(d)\,Dis1 = (Bat1 \ge 35).\overline{Chg1} + (Bat1 \ge 35).\overline{(Bat2 \ge 35)}.(PVCnt = 0)\\
&(e)\,Dis2 = (Bat2 \ge 35).\overline{Chg2}.\overline{Dis1}\\
&(f)\,DsGd = \overline{Dis1}.\overline{Dis2}
\end{aligned} \quad (2)$$

A data center needs a huge amount of energy for IT devices and cooling requirements. For example using Combined Cooling, Heating and Power (CHP) causes a great heat generation. A discussion has been made in [23] about the application of the cooling system and IT devices together. It must be taken into account that a data center consumes a fairly constant energy and only during the night due to the decrease of temperature, power consumption of the cooling system reduces.

3. SIMULATION RESULTS

The data center used for simulations needs 2 MW electric power. The power demand of a data center is rather constant, but %20 decrease of power demand is taken into account at nights within 12 AM and 5 AM due to reduction of cooling system power demand and fewer operation of computational operation of data center. The electric power needed by data center is provided by solar panels and power grid simultaneously.

The system considered for simulation consists of two chargeable batteries, 10000 and 8000 Ah, and also a huge battery with %50 statement of charge which represents the power grid and all of them can be charged by solar panels. Voltage of batteries is 48V and voltage of power grid is 220V. Single phase model of the system is implemented and the simulations are based on the power produced and consumed. Battery Charge Controller controls the process charging and discharging of the batteries based on logical directives. In order to convert DC to AC or vice versa, inverter or converter with efficiency of 0.95 is used.

The irradiance graph of the sun in Tehran is shown in Fig. 2. Since Iran is located in a proper position that absorbs ample amount of sunlight, and the solar power in some areas exceeds 1000 w/m^2, this country has the great potential of using solar power.

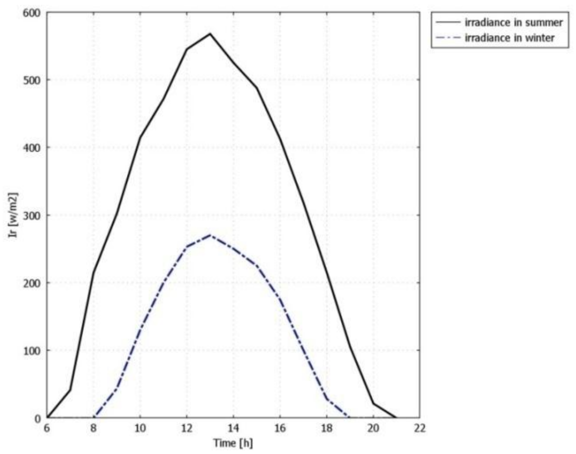


Fig. 2: Irradiance of the sun in Tehran in summer and winter

Fig. 2 shows the solar power of the sun in the Tehran in a day, in summer and winter. As it can be seen these two figures are different, that affects the output power of the PV panels. The data center is located in Tehran, whose geographical coordination is shown in Table 1:

Table 1: Geographical coordination of Tehran

N	E
51°25'23.00"	35°41'46.00"

The amount of sunlight that PV panels absorb, determines the output power of the PV panels. Based on simulations results and also Eq. 1 output power of the PV panels which consist of 10000 panels with 72 cells in series, reaches 1.2 MW at maximum in midday. Anyway it is lower than the power needed by data center most of the time. This fact is illustrated in Fig. 3.

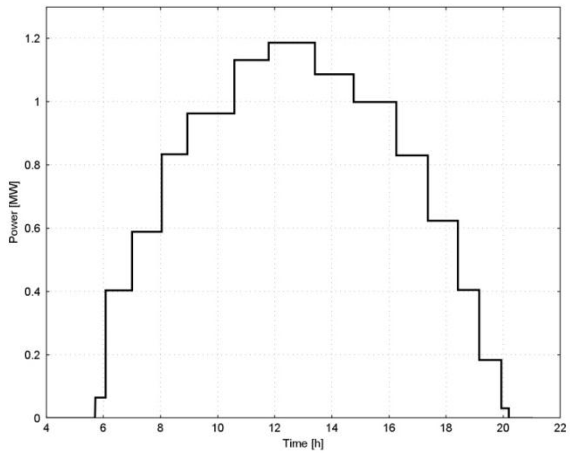
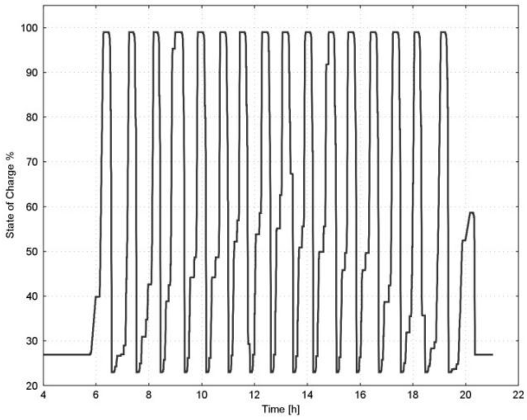


Fig. 3: Power generated by PV panels

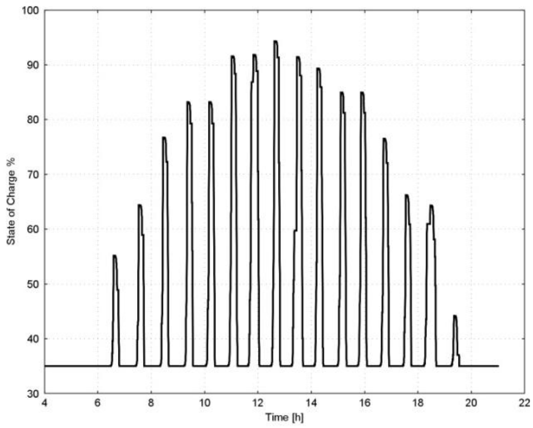
During operation of PV panels, the batteries are charging or discharging. The first battery works as the primary battery, and the second battery is known as backup to enhance the reliability of the system. This battery provides a portion of the load, when the primary battery cannot supply the load. State of charge (SOC) of two batteries is shown in Fig. 4.

As it can be seen in Fig. 4 based on the algorithm of the charge controller, the SOC of the batteries vary between 33% and %99. And also while the primary is charging the backup battery is discharging and supplying the power. In other words it can be said that the backup battery works as the complement of the primary battery.

Providing a continuous power source for data centers is a delicate and important approach. Thus in any data centers power sources other than power grid such as uninterruptable power sources (UPS) and generators, are exploited to ensure the constant source of energy for data center. It must be noted that based on simulation results shown in Fig. 4, Discharging process of the batteries which provides the power needed by the data center, can also act as a power backup supply when power grid fails and is not available. This fact enhances the availability of the power. In [26] it has been discussed that wind energy can be incorporated to supply the energy to feed the data center. It was also discussed [27] its exploitation in data modern electric ships.



(a)



(b)

Fig. 4: Variation of the SOC of (a) primary battery (b) backup battery

In the configuration of the power system considered in this paper the power grid is capable of providing the 2 MW load of the data center and it undertakes the load whenever the sun is not available or batteries are charging and cannot provide the needed power to run the data center. Thus during the intervals which the batteries are charging, the power grid supplies the total load. Figure 5 depicts the power provided by the power grid.

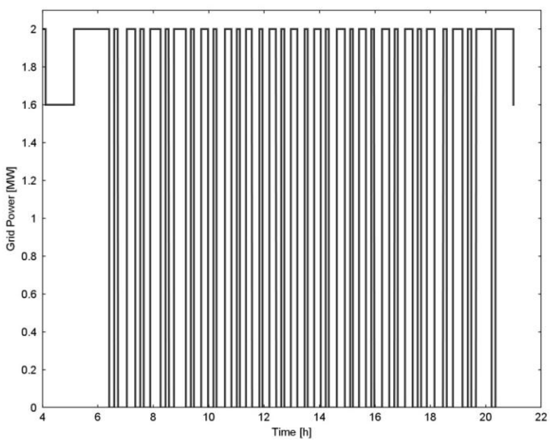


Fig. 5: Power provided by grid

4. CONCLUSION

Based on simulations carried out following results can be concluded:

1) In order to enhance the reliability of the power supply, two or more batteries are needed. But they can be in smaller size. Thus in case of failure of one of the batteries continuous operation of the solar energy supply is guaranteed. It also gives more flexibility to have control over operation of the power supply.

2) It is shown that in the simulated configuration over a week solar energy provides %18 of the total energy needed by operation of the data center. This fact leads to reduction of the cost of the operation. Consequently, it can justify the high amount of capital the solar energy system needs to be installed.

3) Using solar power in a data center in addition to providing power and reducing the air pollution, can increase the sustainability of power system. If the power is supposed to be generated locally for a limited period, for example when power grid is not available, solar power increases the reliability of power system alongside the UPS and generators.

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