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Network Capable Smart Batteries For Smart Grid And Battery Management System.

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Abstract:
Over the last decade, the battery energy storage system (BESS) has become one of the important components in smart grid for enhancing power system performance and reliability. This paper presents a strategy to shave the peak demand and mitigate the voltage unbalance of the electrical networks using a BESS. The BESS is developed to reduce the peak demand and consequently the electricity bill of customers. With the foreseeable large use of BESS, the stress of utility companies can be reduced during high peak power demands. BESS is also equipped with the ability to mitigate voltage unbalance of the network. This indirectly improves the efficiency which in turn, prolongs the life span of three phase machines. The proposed strategy to control BESS has been developed by using the LabVIEWTM graphical programming software. An experimental test bed has been setup at the Universiti Tunku Abdul Rahman (UTAR) campus to evaluate the performance of the system. The experimental results show that the BESS can effectively restrict the power demand from exceeding the pre-determined value and suppress the voltage unbalance factor within the recommended value.

Keywords: Battery energy storage system, peak demand shaving, voltage unbalance.

1. INTRODUCTION

Power demand varies from time to time in accordance with customers' activities. To ensure that the varying power demand is met at all times, smaller capacity power plants such as gas power plants are usually used as standby plants during the peak demand hours. Such standby power plants operate only during the daily peak demand period, typically from 11 a.m. to 3 p.m. In Malaysia, the gas power plants use liquefied natural gas (LNG) that is comparatively more expensive than coal and diesel. Moreover, the gas power plants operate below their rated capacity, hence causing the plants to operate at low efficiencies As a result, the cost of electricity becomes high and so the electricity tariff. The natural gas is expected to be depleted in another after 36 years, based on the reserves and production ratio of 36:1. The price of natural gas is very volatile in recent years. The government has to subsidize the natural gas substantially in order to reduce the cost of electricity. Therefore, the government has to find an alternative means of reducing the use of natural gas and other fossil fuels. The government has launched various programs to promote renewable energies (RE), such as main building integrated photovoltaic (BIPV) Project in 2005, new feed-in-tariffs for RE in 2012, the new forward looking RE policy in 2012 and the feed-in-tariffs for renewable energy sources. The presence of multiple renewable energy sources on the networks can adversely affect the network voltage and stability if there are no appropriate management and control systems. The most common issues are voltage rise, voltage unbalance, reverse power flow, and network losses. The voltage unbalance factor caused by individual loads or DGs should be less than 1.3 % while unbalance at the point of common coupling (PCC), with aggregated effects of several loads or renewable energies, should not exceed 2 % in Europe. This paper presents a BESS that can effectively shave the peak demand and mitigate the voltage unbalance issue. It consists of a battery bank with bi-directional inverters that is integrated with renewable energy sources. The system does not reduce energy consumption of the customers, but only the consumption pattern seen by the utility companies is altered from bell-shaped to flat-top. Under the commercial tariff, this flat-top pattern can reduce the maximum demand charge for commercial customers and hence the electricity bill. If such energy management system is widely spread across the country, the utility companies can reduce the use of standby power plants, hence minimising the peak demands and the cost of electricity. Apart from that, the BESS is able to mitigate the voltage unbalance of the network and improve the quality of network voltage affected by the penetration of renewable energy sources.

2. RELATED WORK

Current energy distribution grid has been in use for almost a century. The aging of equipment's and increasing consumer demands necessitate a revolution in the grid. By 2020, it is foreseen that the energy demand will almost be double the present demand. Increases in recent times in electricity costs and in associated emissions of greenhouse gases are having an impact on societies to adopt business and lifestyle strategies based on sustainability practices.

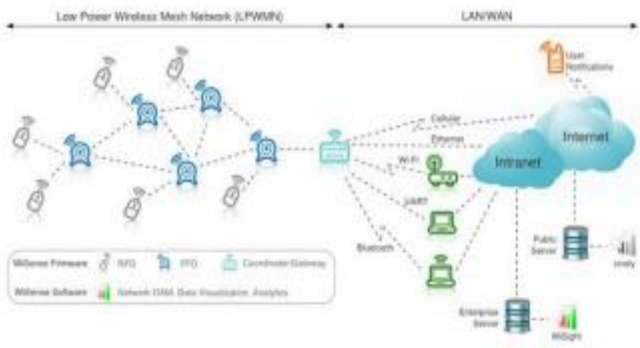

Fig.1.Architecture

The existing electricity grid has remained unchanged for about 100 years. It lacks the capability of providing information and communication. To realize these capabilities, a new concept has emerged the smart grid. Peak demand clipping strategy can effectively reduce the electricity bill for consumers and the cost of electricity for the utility companies. A survey was carried out to identify the potential benefits that the energy management system could bring to the customers. The power consumption in one of the buildings, namely SE block, at UTAR was recorded. The building block comprises of 10 tutorial rooms and 10 laboratories. These graphs show the typical power demand characteristics for colleges and universities in tropical countries where the power demand has a correlation with its weather. The power consumption on Sunday is low because there is no ongoing activity in the building. During weekdays, the power demand starts to rise at about 7.30 a.m. when classrooms start to be occupied. It reaches the maximum demand at 1.45 p.m. when the weather is hot and the air conditioning systems operate at high power. The power demand drops significantly after 5.30 p.m. when students start to leave the building block.

3. PROPOSED SYSTEM

Wireless Sensor Networks (WSNs) are becoming a fundamental tool of the smart grid. Advanced information and communication technologies, monitoring and control and innovative metering technologies via intelligent devices, will become increasingly important. The benefits of the smart grid are not limited to the power distributors but reach both industrial and residential customers as well. By deploying the proper control mechanisms, the power distributor can save money by avoided investments for additional capacity. The industrial and residential customers benefit from green, locally produced power and lower energy bills by automated shifting of flexible loads towards cheaper time windows. To enjoy these benefits, an integrated network for controlling (distributed) energy sources is required. The smart management system is the subsystem in SG that provides advanced management and control services. The smart protection system is the subsystem in SG that provides advanced grid reliability analysis, failure protection, and security and privacy protection services.

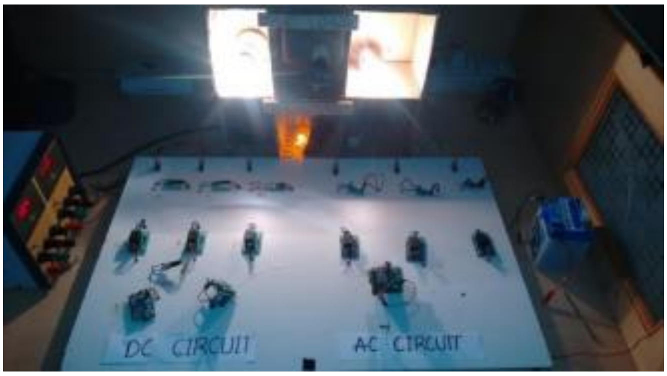

Fig.2.Project system

Hence, in this paper, first the smart demand responsive energy management system under new comprehensive field tests with mesh network design based on AODV for wireless communication is proposed. We present a real-time distributed multi-agent algorithm for coordinating supply and demand in the residential power network in an optimal way. An important goal of the algorithm is to improve the local consumption of the energy produced by solar panels. For optimum utilization of power some data need to be analyzed. Collecting data for analysis from different points and delivering is one of the biggest challenges. The wireless communication technology is key for all the remote monitoring applications. The development of wireless sensor network for integrated communication, sensing and measurement; smart metering and advanced control are some features which are generally developed on smart grid. For proper utilization of power many wireless communication technologies are used for remote monitoring and advanced metering. Renewable energy sources with multiple storage capability are developed. The developed technologies are compared with the present electrical grid technology and percentage of optimizing power utilization is analyzed.

4. ANALYSIS

The battery energy storage system (BESS) consists of a bi-directional inverter that is connected to four sealed lead acid batteries with a total capacity of 480 Ah, equivalent to 5.76 kWh of energy. The National Instruments Single-Board RIO 9632XT is used to monitor the voltage level and output current in the three-phase network. The BESS is placed on a network emulator exclusively designed and developed for this research work. Fig. 2 shows the electrical diagram of the network emulator. The network emulator consists of a series of network resistors, a load bank and a photovoltaic system. The rating of the photovoltaic (PV) system is 3.0 kW. A series of resistors represents the network resistance. The load bank can be varied from 0 W to 5000 W in a step of 500 W. Fig. 3 shows the experimental set up of the network emulator. Renewable energy source costs more but it is one time investment. Solar energy is one of the abundant renewable energy sources. Deploying a solar grid for energy generation and the energy generated from grid is used to charge a battery. From battery we can use the energy during night time where there is no power generation in the grid. For proper management of energy wireless sensor network is designed which can monitor and measure power consumed by all the loads connected.

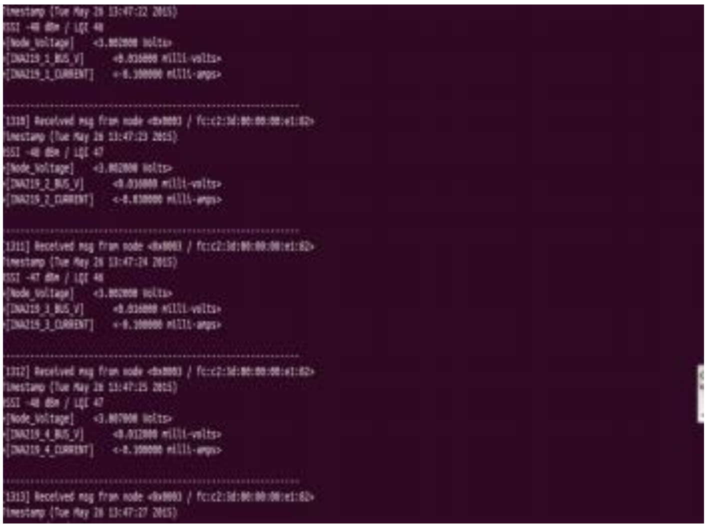

Fig.3.Output

The measured data is transmitted wirelessly to base station from router. The battery charge is also monitored, measured and transmitted wirelessly for proper utilization of it during night time. As if the data are received wirelessly there is no need of metering, user can come to know how much power each component is consuming and try to reduce the utilization of loads consuming more power. Based on the received data the remote switching of the loads can be done. Priorities are given based on the battery charge and electricity generation. For example during night light is necessary compare to motor and other loads hence priority is given to light at night. During day time motor is necessary compare to light hence priority is given to motor. By assigning priority we can utilize energy more efficiently based on necessity. Here we are using a mesh network technology designed based on AODV. The objective of this case study is to study the voltage conditions of the network when the PV inverter is connected to the same phase as that of the load. Fig. 7 shows the experimental results of the VUF, power output of the PV inverter power and the power demand when the PV inverter and the load are at the same phase. At 280 s, the PV inverter begins to inject power into the network and the load starts to increase its power demand, from 0 W, at 420s. The increment of power demand has resulted in the reduction of the VUF from 1.8 % to 0.75 % because the power from the PV inverter is absorbed by the load. This case study shows that the PV inverter can mitigate the voltage unbalance only when power injected into the network is lower than that of the load. If the power injected by the PV inverter is higher than the amount that can be consumed by the load, then the VUF will still be higher than 1 %.

CONCLUSION

In this paper, a battery energy storage system (BESS) is developed for peak demand shaving and voltage unbalance mitigation. Several case studies are carried out for different scenarios of network load and PV inverter. The results obtained show that the BESS can deliver power to grid during peak demand period and absorb power from grid during the off-peak period. The BESS is also capable of handling the voltage unbalance caused by uneven load distribution and integration of PV inverters. Further studies may analyze the optimal sizing of the BESS for peak shaving application to achieve maximal economic benefit.

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