EVALUATION OF POWER QUALITY OF PV-GRID CONNECTED SYSTEM WITH BATTERY STORAGE UNDER LOW RADIATION

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ABSTRACT

At low radiation, the inverter operates at low output power compared to its rated power and this effects the power quality of PV grid-connected system. In this paper, we propose a method to improve the power quality of a PV-grid connected system under low radiation by using a battery storage. The evaluation of this method has been done based on the experimental system at KMUTT, and an economic analysis is made on its system cost effectiveness.

1. INTRODUCTION

We have investigated the effects of radiation levels on power quality of a number of PV-grid connected systems in our previous work. The power quality of the PV-grid connected system depends mostly on the inverter. It is already pointed out that the current total harmonic distortion (THDI), power factor and efficiency depend on the size of the inverter and its output power. At low radiation, the inverter operates at low output power compared to its rated power. Characteristics of inverter concerning power quality such as current total harmonic distortion, power factor and efficiency, depend on a particular model of inverter. In general, the inverter output power less than 20% of the rated power, will have significant change in the power factor, efficiency and %THDI. In Thailand, about 20-30% of solar energy is at low radiation level.

In this paper, we propose a method to improve the power quality of a PV-grid connected system under low radiation by using a battery storage. The battery storage is used to store the solar energy at low radiation level and transfer the stored energy to the system at the other period when the radiation is low and demand of electricity is high. The evaluation of power quality of PV grid connected system using this demand management is made.

2. EXPERIMENT

In order to evaluate the improvement by this method, we set up the experiment using a PV-grid connected system installed in KMUTT. The system consists of PV modules total of 2.73 kWp, single and poly crystalline PV modules and a 2.5 kW single phase grid-connected inverter and a battery bank consists of 20 of 12 V 45Ah (20 hour rate) lead acid batteries. The inverter has two selected mode, with and without MPPT control. The performance of the PV array and the inverter depends on the DC input voltage setting at the inverter and the battery bank voltage determined by the configuration of the batteries. The values of the solar radiation, the temperature of modules and the values of the electrical input and output of the inverter are measured and recorded in the data logger to check if there are significant variations in these values (output power of the PV array, output power of the inverter, %THDI, power factor etc.) by comparing the system with and without battery storage at different battery bank voltages and different DC input voltage settings at the inverter. The power quality parameters are evaluated for different configuration.

3. RESULTS AND DISCUSSION

To maximize the output power from PV array, we found that the DC input voltage setting of the inverter should be set at the voltage as near as the voltage at maximum power. In this case, it should be set at 240V. The battery storage bank should consist of 20 batteries connected in series in order to inject the power to grid through the inverter during low radiation.
3.1 Power Quality of the System

The power quality of the system, THD$_i$, power factor and efficiency, with and with battery storage during low radiation are compared as shown in Fig.1-3. The DC input voltage setting of the inverter is set at 240V and the battery storage bank is consists of 20 batteries connected in series.

![Fig.2](image1) %THD$_i$ of the system with and without battery storage during low radiation.

![Fig.3](image2) Power factor of the system with and without battery storage during low radiation.

![Fig.4](image3) Efficiency of the system with and without battery storage during low radiation.

At radiation less than 150 W/m$^2$, THD$_i$ of the system without batteries is higher than 5% whereas THD$_i$ of the system with batteries is less 1%. Power factor of the system without batteries is lower than 0.8 whereas PF of the system with battery is about 1.0. During such low radiation, the input power mostly comes from the batteries, so the output power of the system could reach the rated power of the inverter, and the better power quality of the system is obvious.

3.2 Economic Analysis

We studied the cost effectiveness of the system with a battery storage. For the reason of energy balance of the batteries, the following assumption is made. The PV system has a battery bank consists of 20 of 12 V 45Ah lead acid batteries. The batteries will be charged by the PV system during 6:00-9:00AM everyday and will be connected to the PV-grid connected system 2 hours during 4:00-6:00PM once in 3 days. Economic analysis is done with consideration of Time of Use (TOU) rate of electricity. The energy is stored in the batteries at the time with low rate and discharged at the time with high rate. The battery life time is considered as 2 years, and efficiency is 80%. The IRR is 8%.

Although we consider the advantage of TOU rate and the efficiency that is higher during low radiation, the analysis shows that the system including battery is not economical.

4. CONCLUSIONS

According to our experiment, it shows an improvement of power quality of PV-grid connected system with battery storage under low radiation. Without consideration of penalty due to low power quality, economic analysis shows that this method is not economical. In the future, this method could be possible if the authority implements a strong penalty charge and the electricity rates climb up due to the scarcity of the energy.

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REFERENCES