Power Quality Improvement and Energy Management of VFD Based Air Conditioning System Using Photovoltaic with Battery Storage

ABSTRACT

In tropical countries, air conditioning system consumes a significant amount of power ($\approx 1.5-3$ kW) from the utility grid and such loads create stress on the grid during peak hours. Photovoltaic (PV) power generation and air conditioning load are directly co-related. Recently with rapid development of power electronics, air conditioners are migrated to operate at variable speeds using variable frequency drive (VFD) technology. In this research work, PV generation and battery energy storage (BES) are integrated to air conditioning system so that the power consumption from the utility grid is reduced. BES compensates the effect of intermittency in the PV generation due to the environmental changes. Considering the advantage of VFD technology, the PV array and battery power is directly injected into the DC bus of VFD using a DC-DC converter without interrupting the main operation of the air conditioner. Due to the high frequency DC-DC conversion, high power DC-AC (50 Hz) conversion stage is eliminated, and seamless power is exchanged between the BES, PV generation and the utility grid. Thus, bulkiness of the system, cost and conversion losses are reduced as well as efficiency and reliability of the system are enhanced. Moreover, the air conditioner system can be operated uninterruptedly even in case of grid failure. As the price of PV panel is getting cheaper day by day, therefore, the one time installation cost of the system is to be compensated with energy bill paid by the user over long duration of time.

As the VFD consists of power electronics switches and diode bridge rectifier (DBR), therefore, the grid current becomes distorted during the operation. As a result, total harmonics distortion (THD) and 3rd harmonic component of the grid current are increased, which creates an adverse impact on the distribution transformer and low voltage power line. In this research work, the power quality (PQ) issues of the air conditioning system are mitigated using power factor corrector (PFC) converter as well as the power consumption from the grid is reduced by integrating the PV power and battery energy storage (BES). Furthermore, the PV generation is used to support the load as well as excess generation is fed back to the grid. A voltage source

converter (VSC) is interfaced at the input stage of VFD, which is controlled to feed power to the grid as well as to improve the waveshape of the input grid current. The PV and BES power is directly injected into the DC bus of VFD by boosting the voltage level of the BES using a dual active bridge (DAB) converter. A seamless power is exchanged in a bidirectional way between the utility grid and BES with improved PQ.

A small-scale laboratory prototype of the system is set up for the validation of the concept. The effect of injecting power at the DC bus of VFD is investigated with different scenarios. Under all test conditions, the THD of the grid current is found within the limits of the IEC 6100-3-2 standard.