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Encompassing nine switch converter approach in wind-hydro hybrid power system feeding three phase three wire dynamic loads

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ABSTRACT

This paper proposes a novel nine switch converter based isolated wind hydro hybrid power system feeding three phase three wire dynamic loads. The proposed system comprises of three generating units and two storage units. In this work, hydro and wind turbine generation system is deployed through squirrel cage induction generator (SCIG) with 50 kW and 40 kW respectively. The main impact of this work is the integration of additional PV unit and two storage units namely battery and ultra-capacitor (UC) into the system through the proposed nine switch converter which was unfeasible through the conventional voltage source inverter. This proposed converter operates in bidirectional mode as either converter or inverter which overcomes the limitation of utilizing additional bidirectional converters. By this novel approach, power can be effectively stored and retrieved from the storage devices through the converter based on the load demand. Sudden increase in load and evaluation under minimal renewable energy support was also studied to evaluate the significance of the proposed system and results are obtained to prove the successful working of the proposed scheme.

Introduction

During the last few decades the costs of acquiring fossil prices has increased tremendously due to high demands and this caused many scientists and other researchers to focus on identifying and developing renewable energy sources. In studies related to renewable energy sources, SCIG has been employed for power generation by small micro hydro and wind systems. Further required reactive power is then provided by the capacitor bank which is located at the stator terminals. Also SCIG has several advantages which include its simple structure, maintenance free nature, tough and sturdy mechanical structure, brushless and much more paramount features in comparison with traditionally deployed synchronous generator that are employed for hydro applications [1–3].

Grid connected variable speed wind energy conversion system (WECS) based upon the use of SCIG was deployed using back to back connected power converters [4]. For these particular systems, SCIG was decoupled by the power converter which in turn decouples from the grid and enhances overall reliability. For grid connected systems that utilize renewable energy sources, total active power may be fed directly to the grid. However, in case of standalone systems that supply local loads, the extracted power exceeds local loads which include losses. If excess power is generated by the wind turbine then it has to be diverted either directly into a dump load or provisions has to be made for it to be stored into the battery bank. Furthermore, if extracted power is lower than consumer load, resulting deficit power, then storage element such as battery bank supplies the remaining power [5,6].

For standalone or autonomous systems, voltage and frequency control (VFC) issues are significant. Researcher's elucidated solutions for VFC related problems in the case of autonomous systems that employ SCIG [7–9]. Studies are also conducted in the area pertinent to stand alone WECS that employ doubly fed induction generator (DFIG). The battery based controller was suggested for VFC issues specifically with respect to isolated WECS [2]. In specific issues of VFC an electronic load controller was located at stator terminals and the controller transfers the power based on the requirement of loads. The proposed work was motivated by the conventional design of isolated wind hydro hybrid system using cage induction generators and battery storage [10]. In the conventional work, load side converter was used as bidirectional converter for storing the excess power to the battery with three different load conditions such as 30 kW, 60 kW and 110 kW. Similarly, the stored power can be retrieved through the same load side converter. But the conventional work may not be able to

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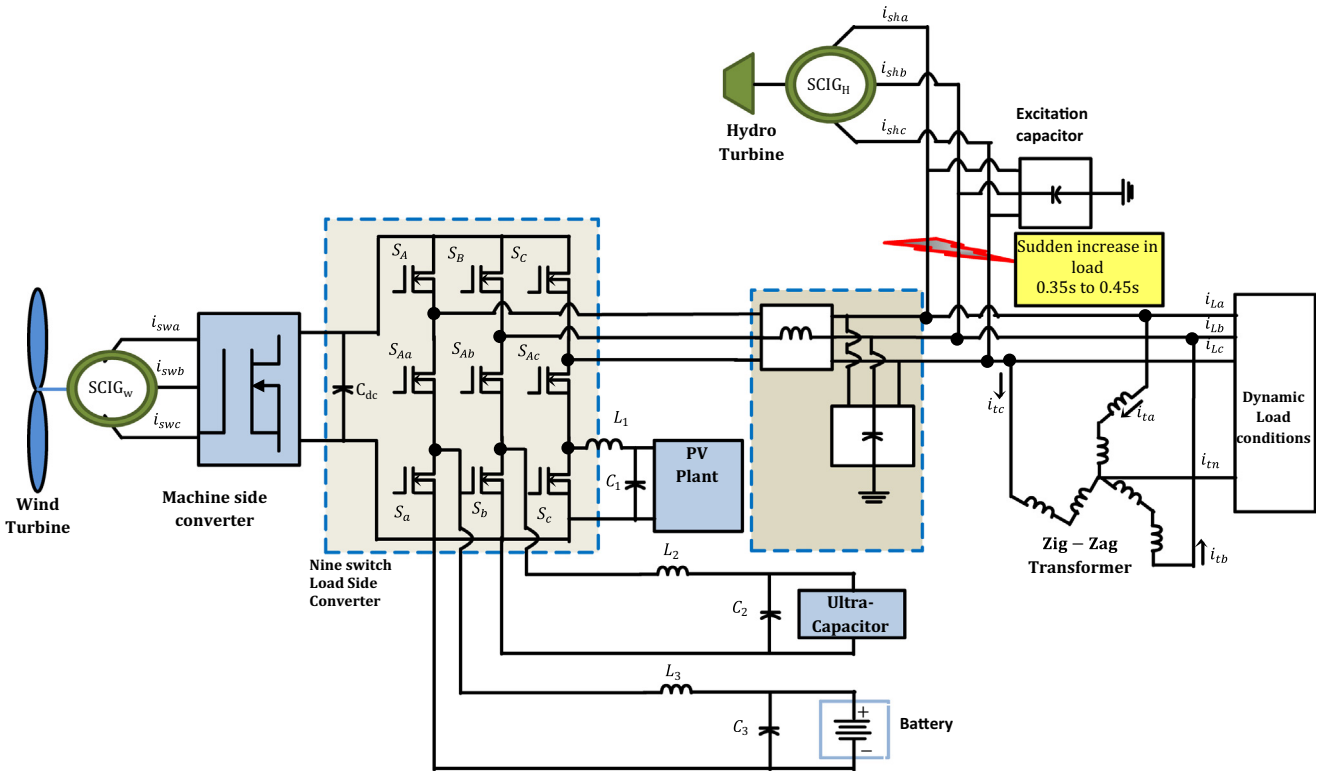

Fig. 1. Proposed nine switch architecture of novel nine switch converter based isolated wind hydro hybrid power system.

integrate other additional energy sources like photovoltaic (PV) panels or additional storage elements such as ultra-capacitors or fuel cells. Hence sudden increase in load may not be supported with the conventional system. As ultra-capacitors are not present in the system, the nonlinear or sudden change in load conditions may not be effectively supported by the battery alone [11]. Also the importance of ultra-capacitors and their advantages was studied and incorporated in the proposed work. The limitations specified in the conventional system may degrade the overall performance of the system during nonlinear load conditions. Hence the limitations may be overcome by incorporating ultra-capacitors into the hybrid system. Research integrating DC/DC bidirectional converter with super capacitors and battery was also considered. The number of switches required for the bidirectional DC/DC converter is observed to be higher which may result in higher circuit complexity [12]. Further the frequency analysis was carried out for permanent magnet synchronous generator (PMSG) type wind turbines [13]. In addition, modeling of wind turbine generator, validation of squirrel cage induction generator to the local grid, power compensation in wind park, variable speed controllers in wind power generators are also studied [14–20].

Factors considered with respect to converter topology and ultra-capacitor

With respect to the converter topologies, traditionally the grid side converter is connected to the grid in shunt configuration and this shunt configuration injects current into the grid. If the grid side converter is connected in series with the grid, the generator stator voltage is effectively the sum of the grid and converter voltages. In the event of a grid disturbance, the series converter voltage compensation for doubly fed induction generator wind turbine low voltage side through solution is also considered [21,22]. A unified converter topology was reported for unbalanced voltage dips and the system shows good tolerance to grid disturbances [23].

Few researchers have shown that the stator voltage need not be hundred percent compensated during the entire period of fault. This was demonstrated by using decaying injected voltage and with time constant less than the stator time constant while still keeping rotor currents within its limits [24,25]. Nowadays as an alternate to the traditional back to back voltage source converter, nine switch converters have been used. The nine switch converter has the advantage of reduced switch count compared to the conventional back to back voltage source converters. However it requires a higher rated DC bus capacitor to produce the same output voltages compared to two level voltage source converters [26–30]. This might overshadow the gains that come with its reduced component count as the switching devices may be unduly over stressed. The advantage in the nine switch converter lies in its auto complementary tuning of shunt and series converters under both normal and sag operating conditions. Under normal operating condition, the shunt converter is modulated to give its maximum output and complementary series converter output is kept almost zero. On the other hand, in voltage sag conditions, a larger output voltage is needed at the series converter output and therefore it can be modulated to give a higher output voltage and consequently a small complementary voltage appears at the shunt output.

With respect to the ultra-capacitor, they are double layer electrochemical capacitor that can store thousand times more energy than a typical capacitor. Ultra-capacitor also shares the characteristics of both batteries and conventional capacitors and has energy density of about 20% of a battery. Moreover, they have almost negligible losses and long life span. They can process a large number of charge (several thousand cycles) compared to normal batteries and only a few thousand cycles for lead acid batteries and can supply much higher currents than batteries. Assisting a hybrid power plant with a parallel ultra-capacitor bank makes economic sense when