Adjustable Speed Generation System For Wind Turbine Power Quality Improvement

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Abstract- **The paper presents an emerging technology of electricity generation based on decoupled theory. The decoupled generation system operates in wide speed range and control strategy is oriented to select regions of high efficiency of the driving engine. This system is used to operate parallel to renewable energy source that is unstable and not reliable. In case of high power available from the renewable the decoupled adjustable speed generation reduces it speed what results in low fuel consumption. However when the renewable source power is decreasing the adjustable speed generation system increases its speed following points of high efficiency of the driving Diesel engine. The paper presents topologies of the combined systems including variable speed wind powered generation system and adjustable speed generation system driven by Diesel engine. Moreover ability of the adjustable speed to provide power is discussed.**

I. INTRODUCTION

The lack of energy, unstable prices of energy, increasing prices of fossil fuels and environment protection result in increase of interest of renewable energy sources. An alternative to fossil fuel based electricity generation are usually wind and solar power. However both wind and solar power depend on weather conditions. Fig. 1 shows an example of typical variation of power as a function of time. There is a load power P_{RL}, renewable source available power P_{RES}, and P_D power demanded to keep stability of the system. The renewable power P_{RES} varies and frequently, in time of high power demand, this power is not available. Therefore the renewable source is mainly source of the energy that reduces general consumption of fossil fuels but not the sources of high quality power. So to provide high quality power, including renewable sources, it is needed to provide an additional generating system that is fully controllable. This additional generation system will compensate renewable power fluctuation and will deliver demanded power P_D at any time. Moreover it is advantageous to use controllable energy storage that acts as instant source of power P_{St}. Fig. 2 shows topology

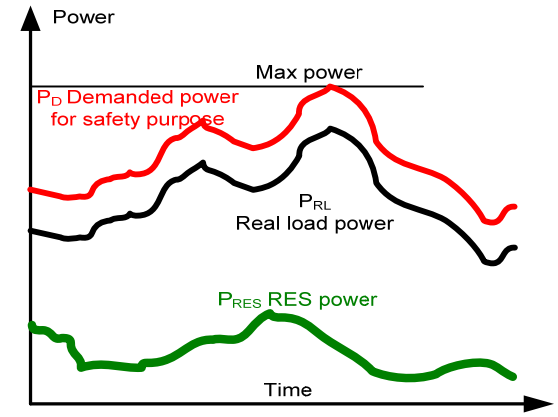

Fig. 1. An example of electricity power demand and renewable available power

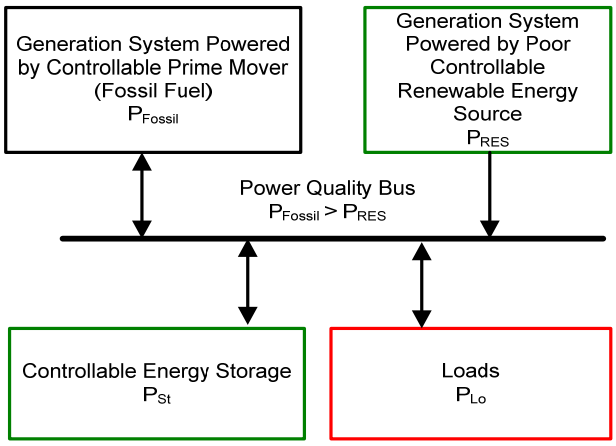

Fig.2. Topology of compensated generation system including renewable and fossil fuel powered electricity sources.

of the generation system that is able to fulfill drawing maximal energy from renewable source (power P_{RES}). Hence the fossil fuel based source power P_{Fossil} produces high quality power and usually is much higher than RES power P_{RES}.

The modern variable speed generation systems based on double fed induction generator (DFIG) are connected to AC bus as is shown in Fig. 3. A synchronous generator SG operates with fixed speed according grid frequency.

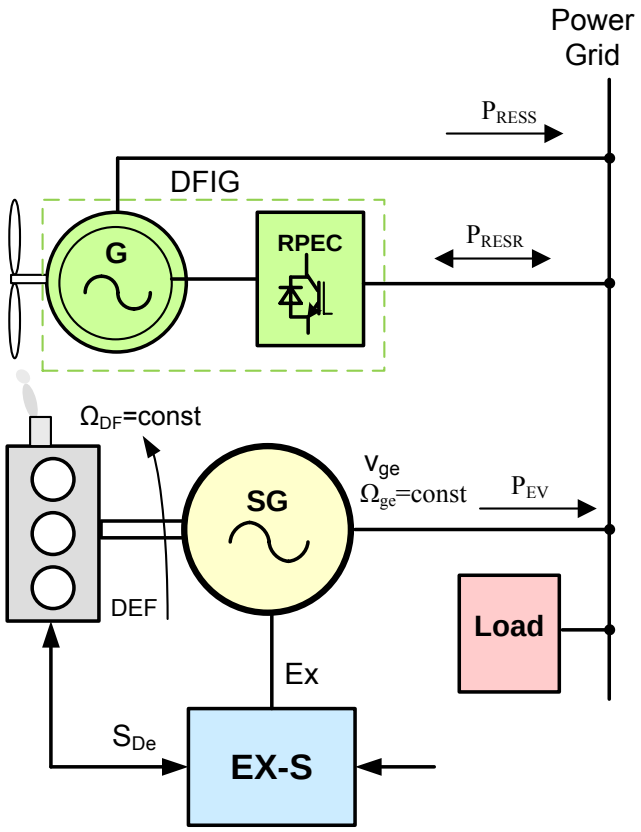

Fig. 3. Typical connection wind turbine DFIG to AC power grid.

The conventional generation system is driven, for instance, by an internal combustion engine [15]. Such system efficiency or specific fuel consumption (g/kWh) depends on load. So, in case of low power demand i.e. in case high power delivered by RES, the specific fuel consumption of the engine is high. Therefore energy saving, responding RES operation, is accorded by significant losses produced by the engine. It is then question how economical is the RES operation?

The fossil fuels are strategy issue of supply countries and fossil fuels prices are not stable and producing great perturbation in world economy. Fig. 4 shows prices of oil during last 60 years. We remember that in Summer 2008 barrel of oil price was much higher than $100. Therefore parallel to great efforts, promoting renewable energy, the same efforts have to be done in the field of reduction of primary energy consumption by improvement of efficiency engines fed by fossil fuels.

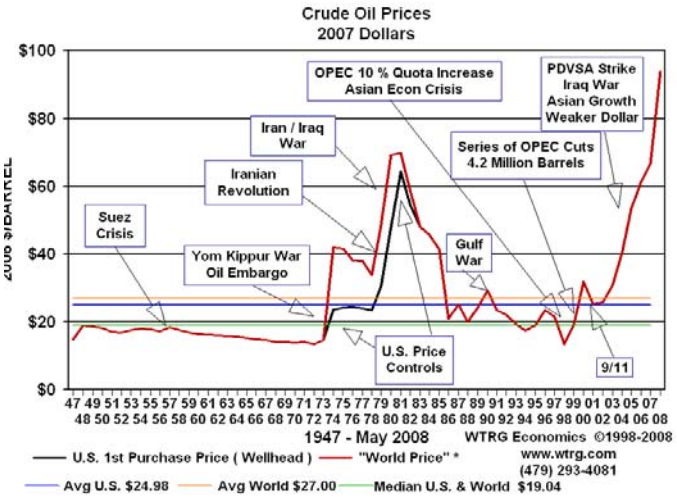

Fig. 4. History of oil prices.

II. ADJUSTABLE SPEED GENERATION SYSTEM APPLICATION

The adjustable speed generation system [1, 2, 5, 14, 16] produces AC voltage that frequency is independent to speed. Such a system (Fig. 5), described as ASGS, is used to

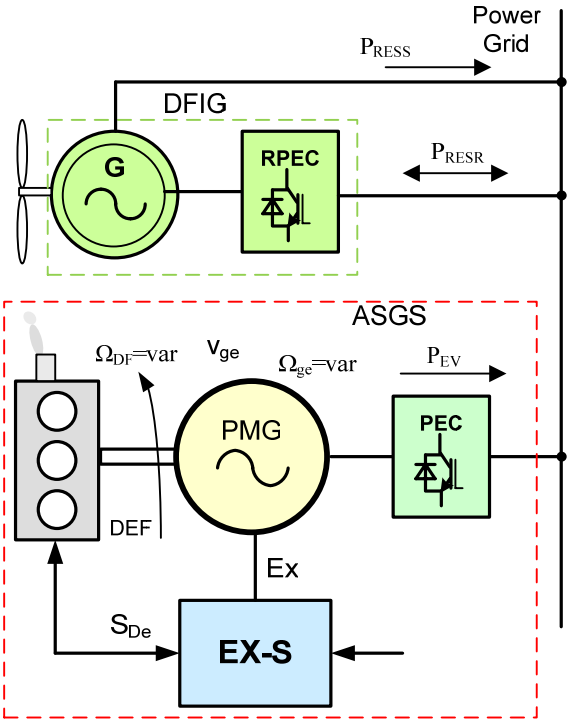

Fig. 5. Decoupled adjustable speed generation system ASGS as efficient generation system connected parallel to wind driven DFIG.

compensate the renewable DFIG power fluctuation. The adjustable speed generation system operates in regions of low fuel consumption. Fig. 6 shows maximal power of the Diesel engine P_{dmax} as function of speed. The adjustable speed

generation system uses engine power along line A_1-A_2-A_3 i.e. in the region of low specific fuel consumption g (g/kWh).

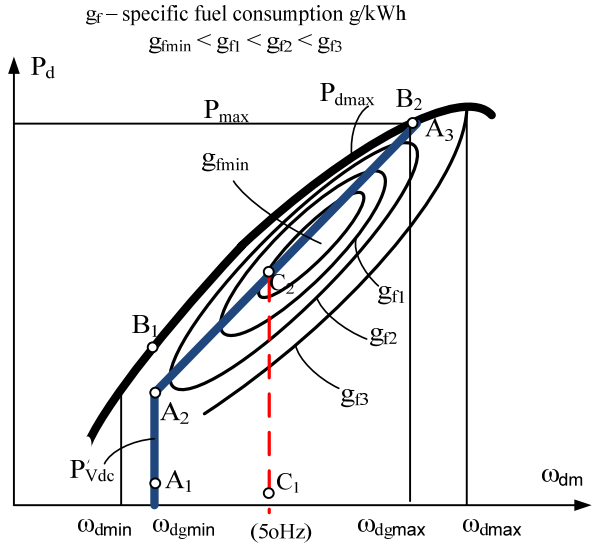

Fig. 6. Power and specific fuel consumption of the Diesel engine operating with fixed and variable speed.

Comparing to conventional fixed speed operation (line C_1-C_2) we do notice that most of fixed speed operation is along high specific fuel consumption.

The adjusted load torque, produced by the generator, is close to maximum torque. So when series of step load appear then speed is adjusted and output voltage (Fig. 7) is maintained

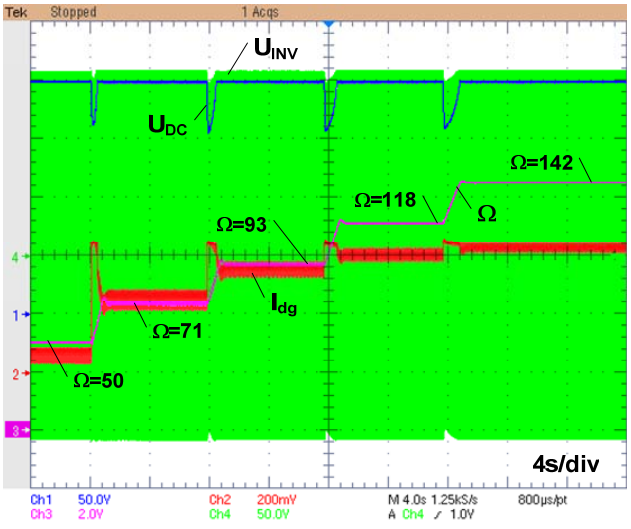

Fig. 7. Response of the adjustable speed generation system on set of step loads.

(voltage $U_{AB\text{-}INV}$). However when at low speed step of high power is applied than output voltage is dropping significantly (Fig. 8)

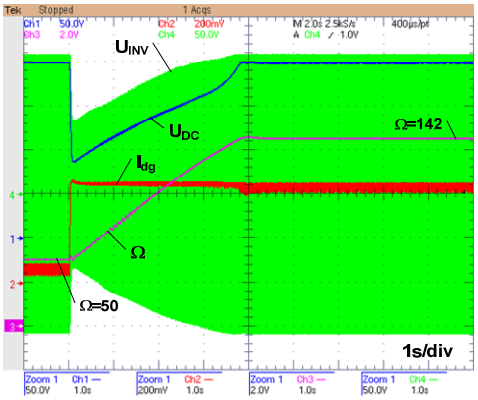

Fig. 8. Response of the speed Ω and output voltage U_{INV} of the adjustable speed generation system on the high step load on the low speed.

To avoid this low quality voltage effect it is used an additional energy storage system shown in Fig. 9.

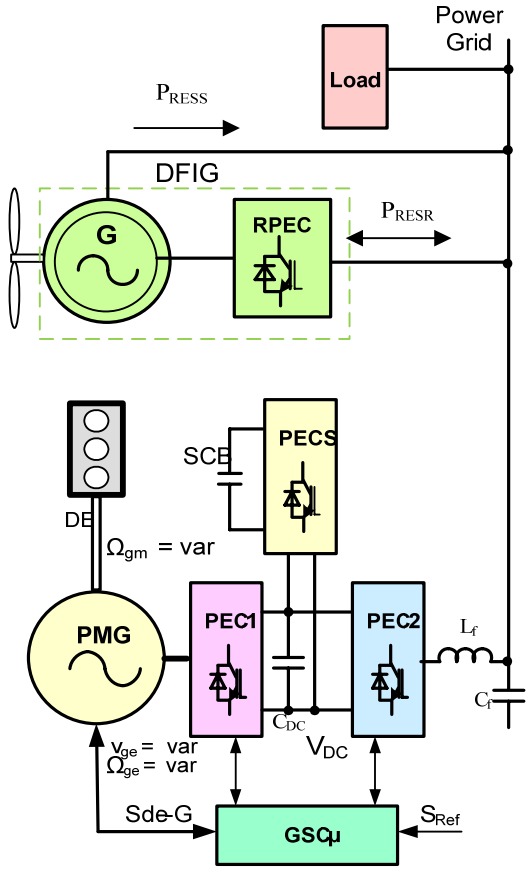

Fig. 9. Topology of the connection of decoupled generation system and variable speed wind powered DFIG.

The energy storage SCE, based on supercapacitor, supplies the load during short time needed to the engine acceleration. An effect of the energy storage application is shown in Fig. 10. The step of load as in case shown in Fig. 10 is not producing

significant voltage changes because the supercapcitor supplies converter DC link voltage U_{DC} by the current I_{sc}.

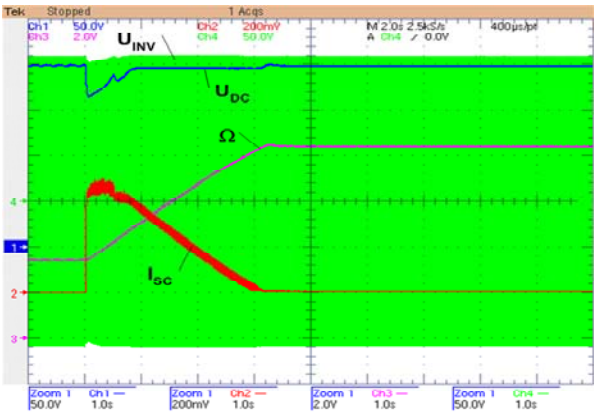

Figure 10. Response of speed Ω, the supercapacitor current I_{SC} and the output AC voltage U_{INV} on high step load at low speed

III. SUMMARY

The adjustable speed generation performances confirm its ability to produce power in region of high efficiency. The system adjusts its power by speed. The maximum power rate is limited by need of speed acceleration. When an addition energy storage is applied then system is able to provide high quality power at any step load. This ability indicates that the adjustable speed may be selected as future system for improvement systems including RES especially wind turbine driven generators.

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