Enhanced Power Quality in Parallel Operation of Hydro Power Generation Using Isolated Asynchronous Generators

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***Abstract*---This paper deals with a power quality improvement in parallel operated isolated asynchronous generators (IAGs) by regulation of voltage and frequency in hydro power stations. The IAGs are driven by uncontrolled micro hydro turbines. The proposed controller consists of an IGBT (Insulted Gate Bipolar Junction Transistor) based 3-leg voltage source convertor (VSC) and a battery at its DC link. The proposed controller is having capability of harmonic elimination, load balancing and load leveling along with the voltage and frequency control. The VSC allows bidirectional flow of active and reactive power; thus it regulates the voltage and frequency. The complete electrical system is modeled and simulated in MATLAB using simulink and SPS (SimPower System) toolboxes. The simulated results are presented to demonstrate the capability of the proposed controller as a voltage and frequency control, a harmonic eliminator and a load balancer for different electrical (consumer load variation) conditions in parallel operated isolated asynchronous generators.**

***Index Terms*---Isolated Asynchronous Generator, Voltage Source Convertor, and Parallel Operation.**

I. INTRODUCTION

The isolate asynchronous generators (IAGs) have widely been recommended for remotely located community by harnessing the available of renewable energy sources like micro hydro, wind and biogas. Because of having its brush less construction, small size, no DC supply for excitation, less maintenance cost and improved terminal performance [1]. The isolated asynchronous generator may be operated in parallel to meet the increased electric load demand and for full utilization of the generated power. Parallel operation of isolated asynchronous generators is required for demand of increased loads and these generators are superior compared to other electric generators because there is no need of synchronization between two asynchronous generators. But after having certain advantages poor voltage and frequency regulation is the major bottleneck in their commercialization, so need of effective voltage and frequency controller for power quality improvement in parallel operated IAGs.

A number of attempts have been made in the area of developing voltage and frequency controller for isolated asynchronous generators driven by uncontrolled Pico, and micro hydro turbines or wind turbines in constant and variable power application [2-5] of isolated asynchronous generators. Research work has also been carried out to investigate the controllers [6], steady state analysis and modeling of parallel operation of isolated asynchronous generator [7-10]. However an attempts is made here to investigate power quality improvement for parallel operated IAGs. The proposed controller is using voltage source converter with battery at its DC link [11] for supplying the required reactive power, harmonic elimination, load balancing and regulating the voltage and frequency of the proposed electrical system.

II. SYSTEM CONFIGURATION

Fig.1 shows the system configuration of proposed isolated electrical generating system along with its controller. The battery energy storage system and VF controller connected between two isolated asynchronous generators. The proposed controller consists of IGBT based current controlled VSC along with a battery at its DC link. The output of the VSC is connected through the AC filtering inductors to the IAGs terminals. The delta connected individual capacitor banks are used to generate the rated voltage at no load while additional demand of reactive power to regulate the voltage is fulfilled by the controller because of having a capability of bidirectional flow of active and reactive powers of voltage source converter. The basic principle of regulating the frequency by the controller is that it maintains the constant output power at the generators terminal because input power from the turbine is constant so the frequency at the terminals remains constant. If the consumer becomes load is less than generated power then additional power is used to charge the battery, if consumer load becomes higher than generated power, the battery supplies the active power through discharging so the total load at the generators terminals remain constant at all time which in turn maintains the system frequency constant. Then the system power quality automatically improved.

III. CONTROL STRATEGY

Fig. 2 shows the control scheme of the controller to regulate the terminal voltage and frequency of the generator which is based on the generation of reference source currents.

It has two components in-phase and quadrature, with AC voltage. The in-phase unit templates (u_a, u_b and u_c) are three-phase sinusoidal functions, computed by dividing the AC voltage va, vb and vc by their amplitude Vt. Another set of quadrature set of unit templates (wa, wb and wc) are sinusoidal functions obtained from in-phase templates (ua, ub and uc). To regulate the AC terminal voltage (Vt), it is senced and compared with the reference voltag (Vref).

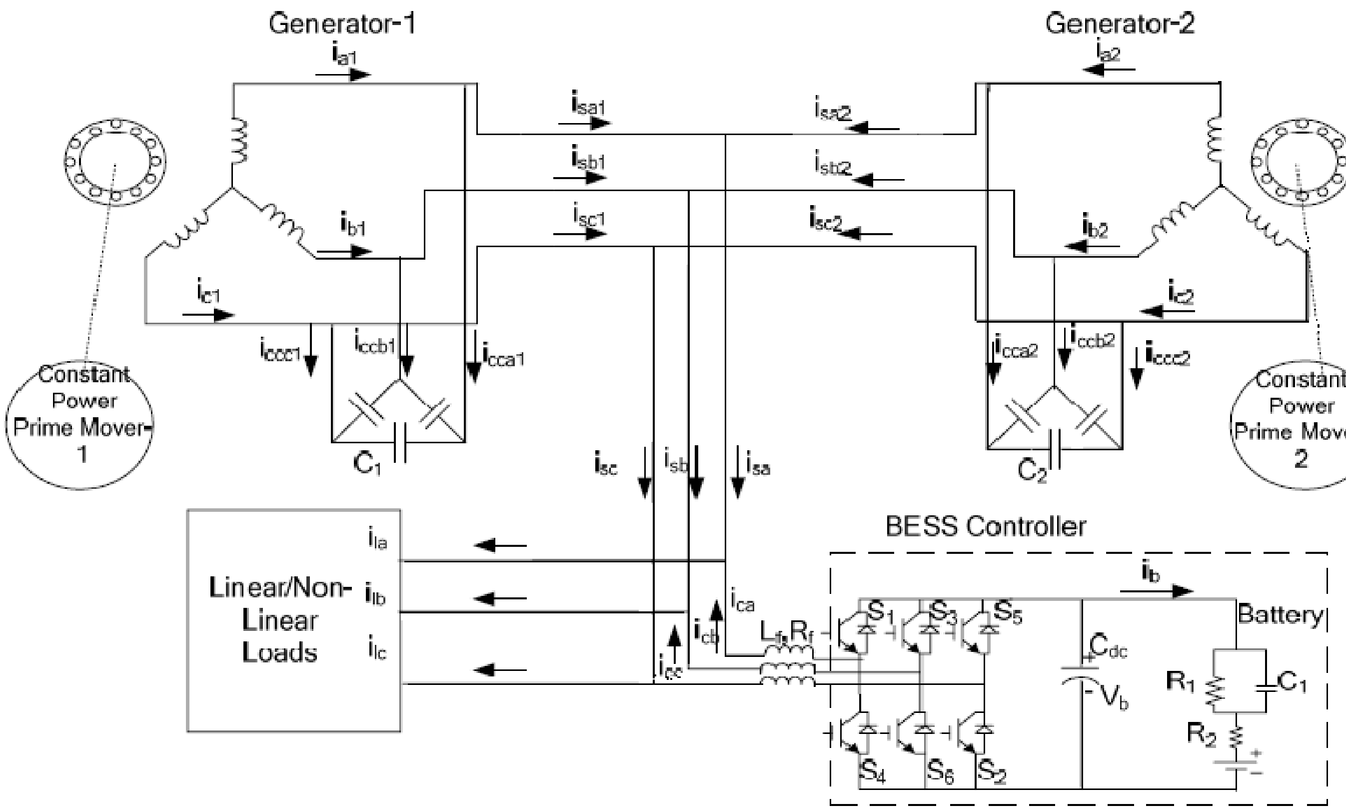

Fig. 1. Schematic diagram of parallel operated isolated asynchronous generators

The voltage error is proposed in the PI controller. The output of the PI controller (I*smq) is the amplitude of the reactive current or quadrature component of the reference source current.

Verror = Vref - Vt

Where Vref is the reference voltage and Vt is the three phase terminal voltage. The output to be generated by the controller. Multiplication of qudrature unit templates (wa, wb and wc) with the output of the PI controller (I*smq) yields the reactive or quadrature component of the reference source current.

the reference source current (I*saq, I*sbq and I*scq) to control the voltage. For constant power generation, the active power component of the source current is fixed at rated values. That the amplitude of in-phase component of source current (I*smd). Multiplication of in-phase unit templates (ua, ub and uc) with in-phase component of source current (I*smd) yields the inphase component of the reference source currents (I*sad, I*sbd and I*scd). The instantaneous sum of quadrature and in-phase components of the source currents provides the reference source currents (i*sa, i*sb and i*sc). These are compared with the sensed source currents (Isa, Isb and Isc) and these current error signals are used in the hysteresis current controller to generate the PWM gating signals for IGBTs of the current controlled voltage source converter.

IV. Control Algorithm

In fig. 2 Basic equations of the control scheme of the proposed controller are given as fallows.

A. Quadrature Component of Reference Source Current

The AC voltage error is equals to change of reference voltage and amplitude of the terminal voltage.

Of the proportional integral (PI) controller (I*smq) for maintaining the constant AC terminal voltage. Hence the quadrature component of the reference source currents is computed as:

I*saq = I*smq wa; I*sbq = I*smq wb; I*scq = I*smq wc

Where wa, wb and wc are the quadrature unit templates having a phase shift of 90^0 leading the corresponding unit vectors ua,ub and uc. Which are computed as:

wa = -ub/sqrt3 + uc/sqrt3; wb = sqrt3/2 (ua) + (ub - uc)/ 2sqrt3
wc = -sqrt3/2 (ua) + (ub - uc)/ 2sqrt3

B. In-Phase Component of Reference Source Current

The instantaneous line voltages va, vb and vc are considered sinusoidal and hence their amplitude is computed as:

The in-phase unit templates with va, vb and vc are derived as:

$$Vt = sqrt((2/3) (va^2 + vb^2 + vc^2))$$

$$ua = va/Vt; ub = vb/Vt; uc = vc/Vt$$

For the constant power applications, the IAGs should be generating constant active power. For the constant power in-phase component of reference source current (I*smd) is equals to the rated amplitude of active power and voltage which is computed as:

$$I^*smd = sqrt2 (P_{rated}) / sqrt3 (V_{rted})$$

Where P_{rated} and V_{rted} are total rated power of both the generators and rated voltage.

The instantaneous values of the of in-phase components of reference source currents are computed as:

$$I^*sad = I^*smd\ ua;\ I^*sbd = I^*smd\ ub \text{ and } I^*scd = I^*smd\ uc$$

C. Reference Source Currents

Reference source currents are sum of in-phase and quadrature components of of the reference source currents as:

$$i^*sa = I^*saq + I^*sad$$

$$i^*sb = I^*sbq + I^*sbd$$

$$i^*sc = I^*scq + I^*scd$$

D. PWM Current Controller

Reference source currents (i*sa, i*sb and i*sc) are compared with sensed source currents (Isa, Isb and Isc). The ON/OFF switching patterns of the IGBTs gate signals are generated from the PWM current controller. The current errors are computed as:

$$isaerr = i^*sa - Isa$$

$$isberr = i^*sb - Isb$$

$$iscerr = i^*sc – Isc$$

These current error signals used in the PWM hysteresis current controller to generate the gating signals for IGBTs of VSC.

V. MODELING OF THE PROPOSED SYSTEM

The fig.3 is the complete electrical system along with its controller is modeled in MATLAB version of 7.7 using simulink and SimPower System block set. A 22kw, 415v, 50Hz 4-pole Y-connected asynchronous machines are used for isolated parallel operation. The battery based controller consists of a current controlled voltage source converter in fig. 1.Thevenin equivalent circuit of a battery based model [7] is shown at dc link of the controller. The battery is an energy storage unit; its energy is represented in kwh. In the thevenin equivalent model of the battery, R_2 is the equivalent resistant parallel combination of a battery, which is usually a small value. The parallel circuit of R_1 and C_1 is used to describe the stored energy and voltage during charging and discharging. Here the battery having 18kw for 8Hrs peaking capacity and with the variation in the voltage of order 790v-810v, the battery specifications and constant prime mover characteristics are shown in APPENDIX.

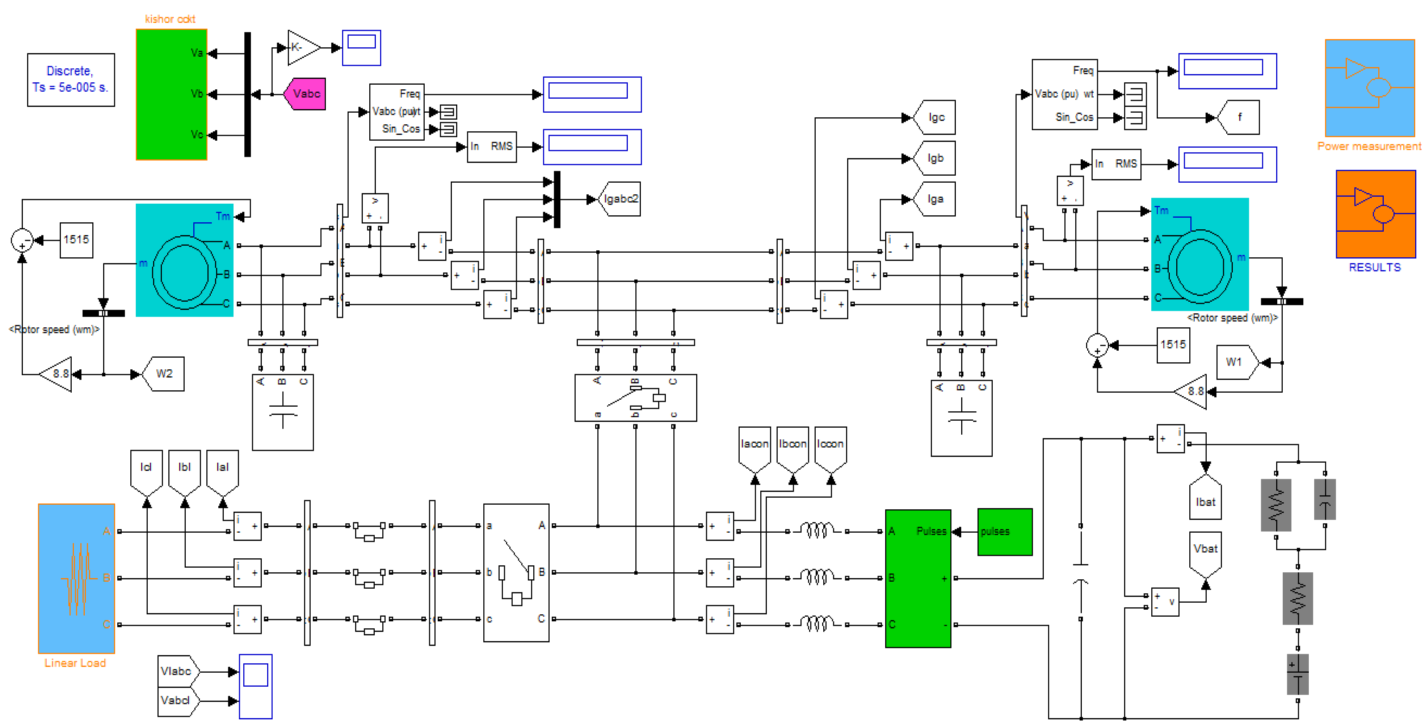

Fig. 2 MAT LAB simulink model of the parallel operation of isolated asynchronous generators

VI. RESULTS AND DISCUSSION

The parallel operation of isolated asynchronous generators performance is demonstrated with balanced /unbalanced, linear and non linear loads. The simulated results are as generator voltage (Vabc), generator currents (Igabc1, Igabc2 and Isabc) , system frequency (f), and various powers(p) which are generating power (Pgen), load power (Pload) and controlled power (Pcon) at the different dynamic conditions are shown in fig. 3 for linear load.

Fig. 3 shows the performance of the parallel operation of the IAGs with balanced /unbalanced resistive consumer loads of 46kw. Before applied a consumer load, the battery consumes all generated active power. The linear load 46kw applied at 2.6sec, then the load observed high power requirement so the battery supplies additional power required by consumer loads. The function of battery is achieved for load leveling and a constant power is maintained at generator terminals. At 2.7sec one phase of the load is opened and load becomes unbalanced then the observes the additional power that means battery churching. And again at 3.0sec closed that phase and load becomes balanced, then the battery supplies additional active power to the consumer load.

Again the full load is removed at 3.3sec, the battery starts charging by the all generated power. So this way the battery charging and discharging and also this controller keeps the generated power constant and improved power quality by maintaining terminal voltage and frequency.

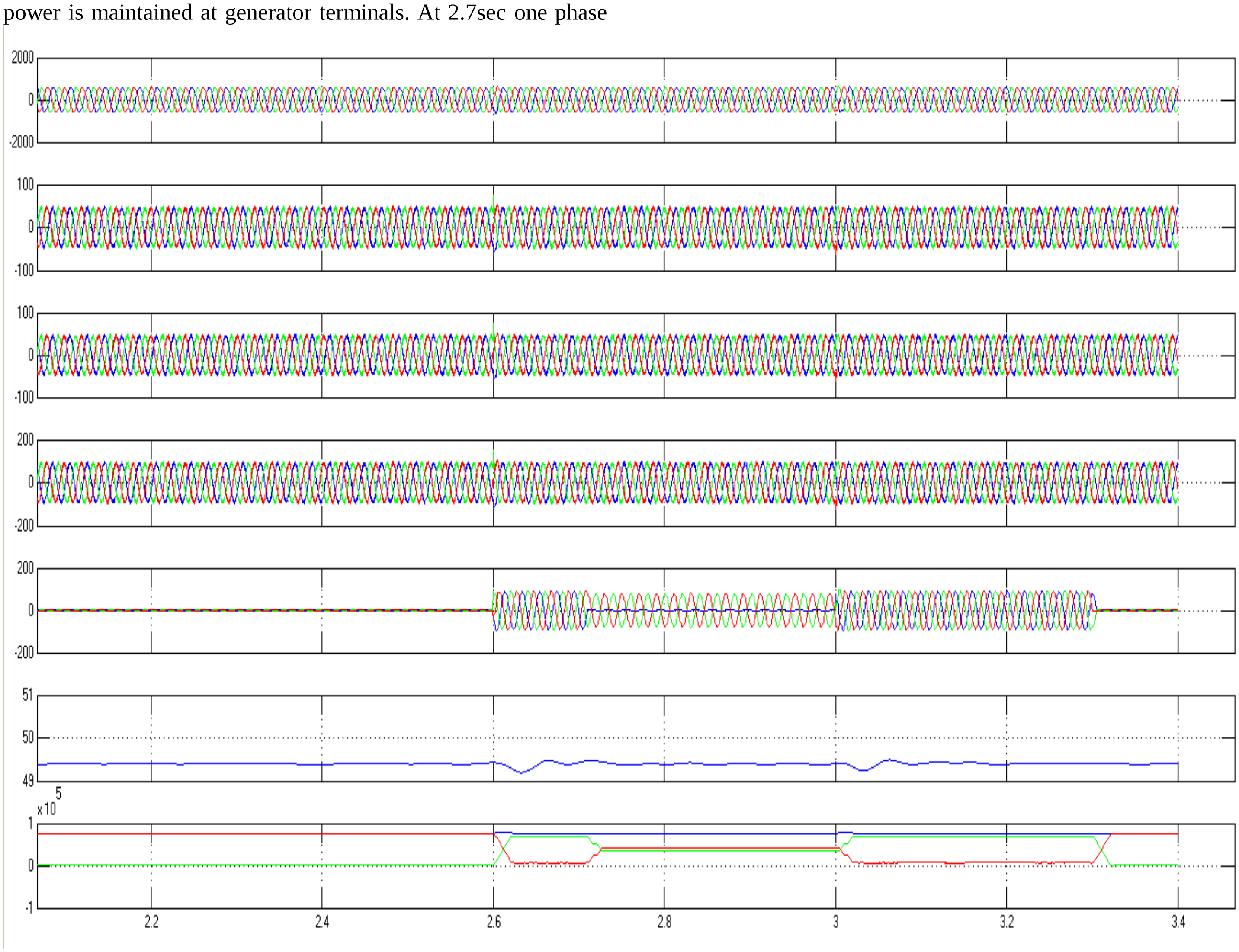

Fig. 3 simulation results of generation of voltage (Vsabc), generation of current 1 (Igabc1), generation of current 2 (Igabc2), source current (Isabc), load current (Iabcl), frequency (f), load power (p) respectively.

VII. Conclusion

The performance of a battery energy storage system based voltage and frequency controller for parallel operated isolated asynchronous generators has been demonstrated for load leveling, voltage and frequency regulation. The proposed controller is having good capability for harmonic elimination, load balancing, load leveling and voltage and frequency control.

The VSC allows bidirectional flow of active and reactive power; thus it regulates the voltage and frequency. MATLAB based simulation results have shown the satisfactory performance for the proposed electrical distribution system feeding linear loads.

VIII. APPENDIX

A. *Parameters of 22kw, 415v, 50Hz, Y-Connected, Four-Pole Asynchronous Machine*

Rs = 0.2511Ω, Rr = 0.77Ω, Ls = Lr = 0.00139H

J = 0.305kg.m^2 Lm = 0.0591H

B. *Prime Mover Characteristics for 22kw Machine*

Tsh = K1ωm–K2, K1 = 8.8, K2 = 1515

C. *BESS controller parameters*

Lf = 4mH, Rf = 0.1Ω, and Cdc = 6500μF,

R1 = 10k, R2 = 0.1Ω and C1 = 15000F,

Kpa = 0.17, Kia= 0.03.

D. *Consumer Load*

Linear load = 44kw.

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