# Wind based Phase-Fault Tolerant Induction Generator for Grid-secluded Application

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## 1. Introduction

- The usage of renewable sources of energy such as wind and solar photovoltaic (PV) has become critical with an increased global energy demand and with soaring fossil fuel costs.
- A suitable standalone renewable source of generation is thus the need of the hour especially in developing countries.
- In this paper, three-phase induction machine is used as generator for supplying single-phase grid-isolated loads.
- For this purpose, a balanced excitation is provided in the stator which makes the IG work like a two-phase generator.
- The three-phase IG can be used as a single-phase IG when there is a phase-fault and any one of the phases are shorted.
- A capacitor bank is connected across the stator winding terminals for initial bulk excitation. An inverter is connected across the stator terminals for providing variable excitation.

## 2. Asymmetric Excitation

- In three-phase SEIG, the reactive power source helps to maintain the magnetic field and it is almost often a three-phase capacitor bank.
- It is also observed that even if instead of a three-phase capacitor bank, a single-capacitor is connected across a phase and neutral, similar excitation will take place and generation of voltage will take place across other phases.
- The same is also true with a suitable valued capacitor when connected across two-phases and one phase and neutral kept open.
- This self-excitation phenomena was also used previously for short duration dynamic braking of induction motor.
- The problem is when this phenomenon is utilized for generation purpose, there are long term effects of this unbalance, leading to unbalanced current flow in stator and finally culminating to phase-faults due to excessive heating.
- The unbalanced currents also lead to torque pulsations which damages the motor mechanically.

- Induction machine electromagnetic torque using the sequence currents can be given as,

$$T = {}^{3P}\!/_{2} L_m \operatorname{Im}\left[ (I_{sp} I_{rp}^{*}) + (I_{sn}^{*} I_{rn}) + (I_{sp} I_{rn} e^{j2\omega_s t}) + (I_{sn}^{*} I_{rp}^{*}{}^{-j2\omega_s t}) \right]$$

- Interactions from the positive and negative sequence current vectors produces electromagnetic torque which is useful and the dissimilar quantities of positive and negative sequence current vectors produce a pulsating torque with twice stator frequency which can cause torque pulsations which are harmful to the IG.
- A suitable control to minimize this effect is discussed in the paper which can be suitably used during phase-faults in SEIG.

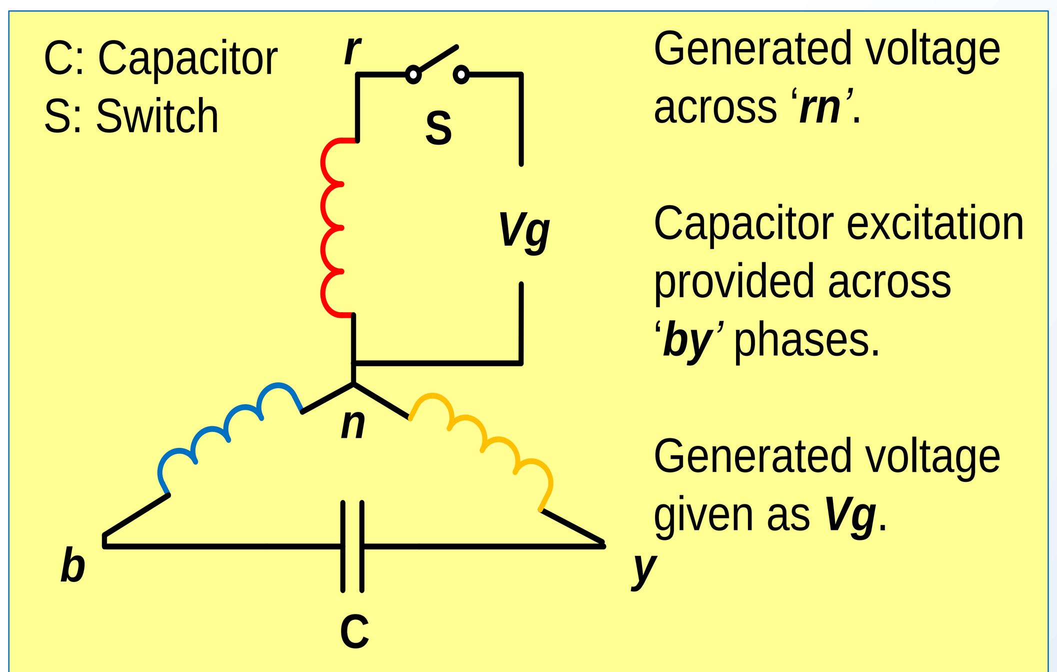


Fig.1. Asymmetric excitation for SEIG.

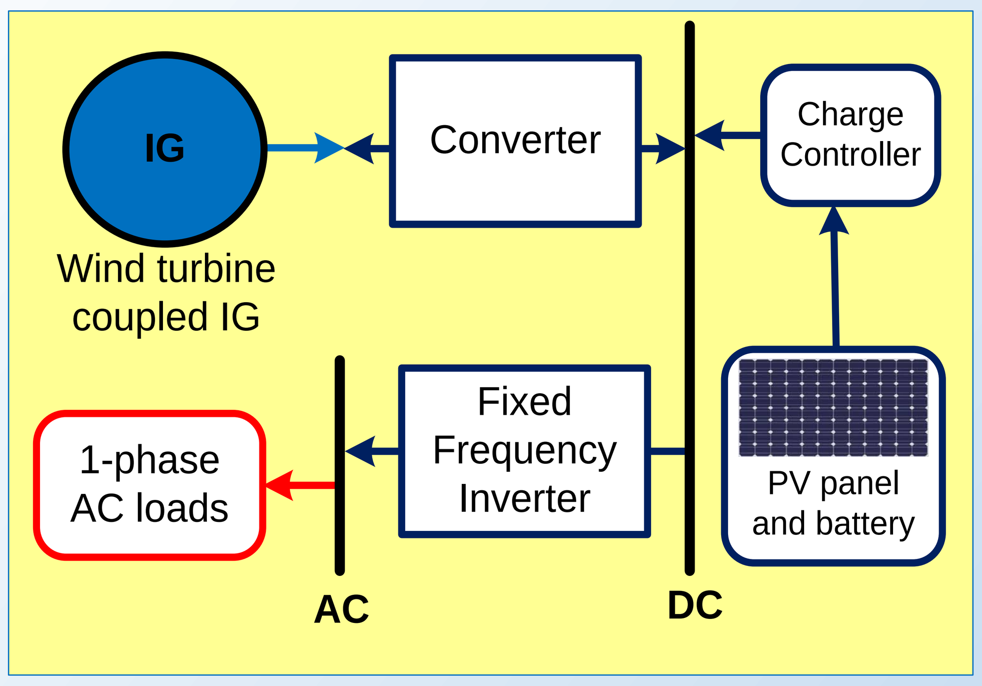


Fig.2. Proposed isolated generation scheme.

### A. Normal operation

- When there is no phase fault, the three-phase IG operates normally just like any other three-phase wind turbine generator.

### B. During phase-faults

- During a phase fault when one of the IG windings is having a fault, the IG is operated in asymmetric mode as shown in Fig.3.
- In this condition of operation, the control scheme is shown which provides balanced current flow in the stator winding thereby reducing torque pulsations and improving machine life. Also, it should be noted here that during such an operation. Only about 90% of power can be obtained than normal three-phase IG operation theoretically without exceeding the machine current ratings of the windings.
- A hysteresis band controller (HBC) is used for the inverter control to provide balanced current control for switching the inverter. The inverter used in this case is in single-phase configuration. Thus, an extra leg of inverter is needed for the said operation.

## 3. Proposed Control for the IG During Phase Failure

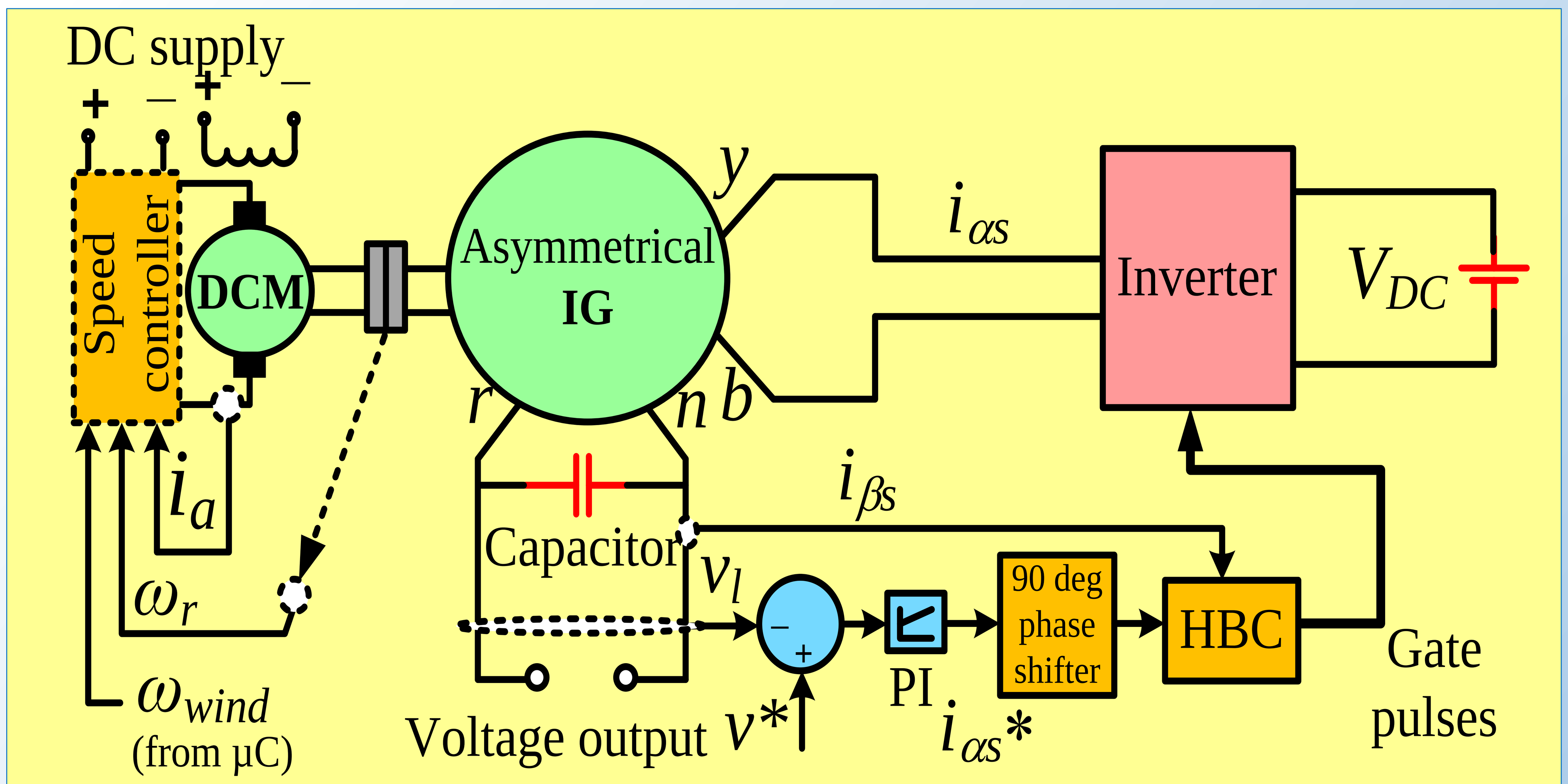


Fig.3. Proposed IG with control scheme during phase fault (asymmetrical IG operation).

## 4. Results

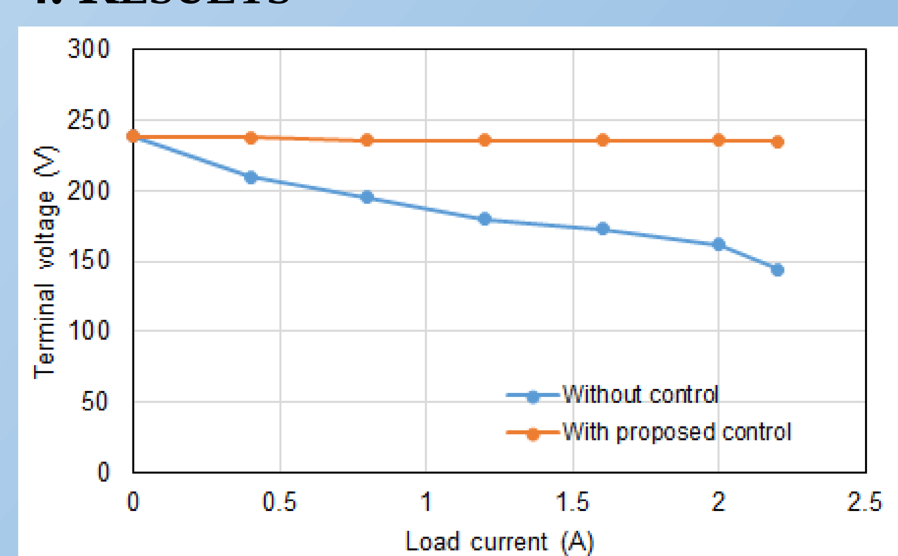


Fig.4. Terminal voltage variation with load current during phase fault with and without proposed control.

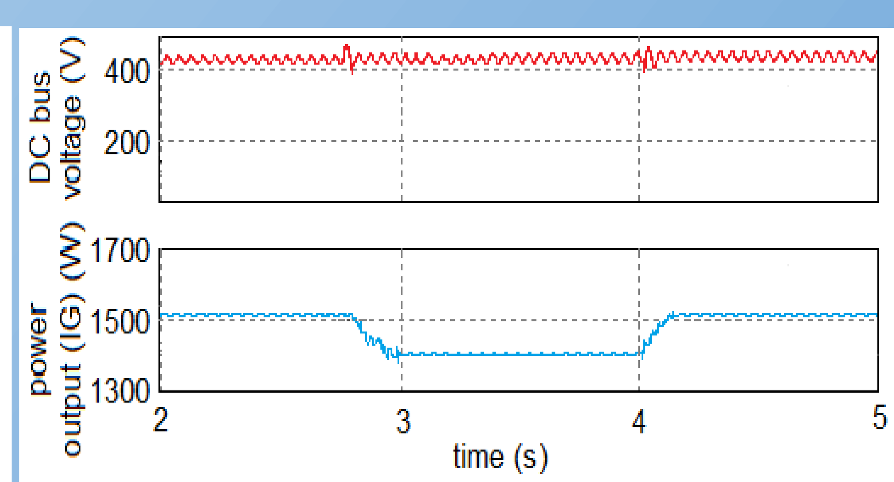


Fig.5. Variation of DC bus voltage and power output from the IG with phase fault.

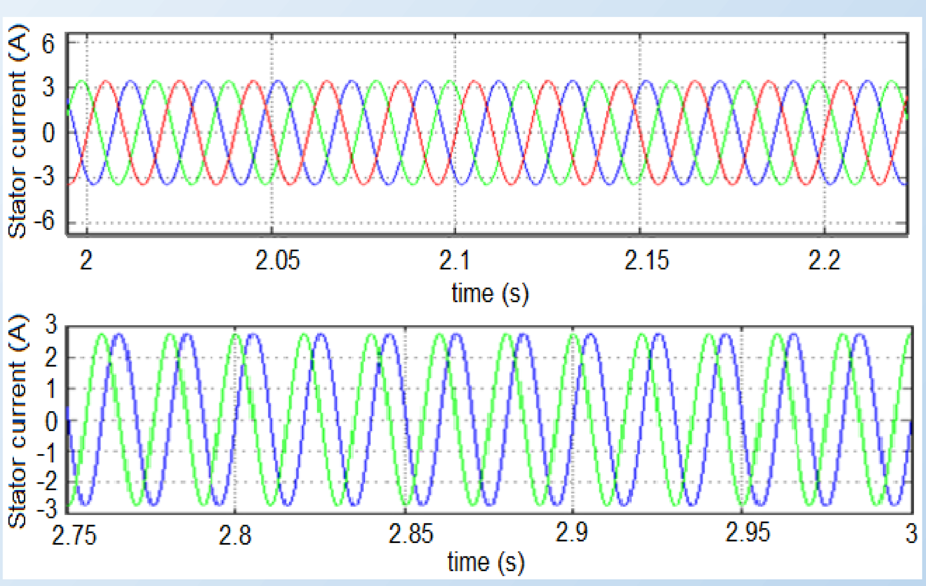


Fig.6. Stator currents during normal three-phase IG operation at rated load and stator currents during balanced asymmetric IG operation with rated load.

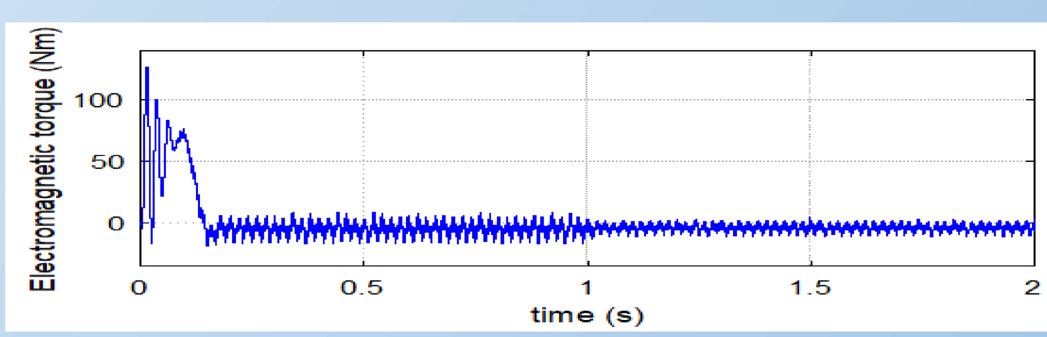


Fig.7. Electromagnetic torque pulsations for the IG when operated in single-phase asymmetrical mode. (Proposed control applied after 1s).

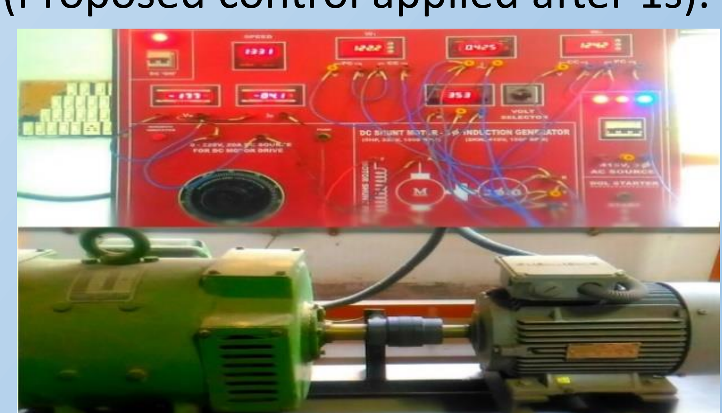

Fig.8. Laboratory experimental test rig.

## 5. Conclusion

- The control scheme during phase-fault operation is maintained at two-phase balanced mode as proposed in the paper.
- The generation scheme can be easily fabricated in remote and grid isolated areas with a wind turbine for domestic microgeneration applications.
- The proposed control strategy also overcomes the problem of voltage regulation during variable load or wind speeds.
- A PV panel also aids in the operation of the IG during low or no winds.