SYNCHRONIZING AND PROTECTION RELAY FOR DISTRIBUTED GENERATORS

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ABSTRACT

An innovative approach for essential pre-synchronization condition satisfaction by a sync-check relay for a distributed generator to be connected with the power system for parallel operation is presented. Design procedure for each condition checking and governor speed and excitation voltage control criteria is discussed. The researched novel methodology for detection of correct instance when the generator and the power system are in phase is discussed and its implementation is further illustrated. Necessary protection functions for the safe operation of generator and prime mover and the implementation are also included.

***Key words*:** sync-check relay, distributed generator, pre-synchronization

1. INTRODUCTION

When closing a circuit breaker between two energized parts of the power system, it is crucial to match voltages on both sides of the circuit breaker before closing. If this matching or "synchronizing" process is not done correctly, a power system disturbance will result and equipment such as generators can be damaged. Therefore in order to correctly synchronize the generator specific set of conditions must be satisfied.

Before the generator is connected to the grid, certain essential pre-conditions must be satisfied in Synchronizing procedure. The generator in comparison with system must have

1. The same rms voltage.
2. The same frequency and phase sequence.
3. The same phase position

At the correct instant these conditions are guaranteed, breaker is operated in order to connect the generator in parallel with system. Today these are digital microprocessor instruments, but in the past electromechanical relay systems were applied. Loss of synchronization can occur because of multiple reasons, but causes severe amounts of damage if not stopped. Also, protection system must be able to detect and disconnect the generator from the system as soon as possible before any harmful effects take place. [5] Sync-check relay electrically determines if the difference in voltage magnitude, frequency and phase angle falls within allowable limits. The allowable limits will vary with the location on the power system. Typically, the further away from generation and load, the more phase angle difference can be tolerated. [3][4].Following table shows the relevant standard ranges of interconnections of distributed generators to the power system. [1]For testing purposes a 0.3kVA synchronous generator coupled with a DC motor is used.

2. METHODOLOGY

2.1 Frequency Controlling

In order to set the difference of frequencies of the generator and the supply side according to

the relevant tolerable ranges, frequency controlling is needed. Also terminal voltage of a synchronous generator is proportional to the rotating speed of the rotor and to the excitation current in the field winding. Therefore to control the terminal voltage by controlling the excitation current, rotor angular velocity must be kept constant. Hence the frequency controlling should be introduced.

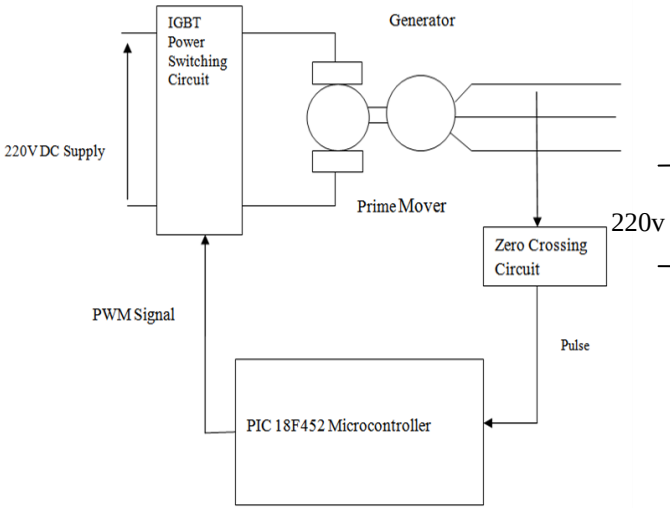

Fig 1: Frequency controlling block diagram

Frequency detection circuit consists of three sections

1. Voltage Divider
2. Zero Crossing Detector Circuit
3. Frequency calculation inside the microcontroller

The Zero Crossing circuit detects the zero crossing instances of the output voltage waveform. When the output voltage goes to zero the circuit will generate a pulse. The waveform goes to zero only once during a cycle. i.e. pulse frequency is same as the terminal voltage frequency. These pulses are fed in to the microcontroller PIC18F452A as an interrupt. Pulses generated by the zero crossing detector circuit are fed to the microcontroller as an interrupt. Here PIC18F452 microcontroller is programmed to detect the frequency. The system frequency is given as the reference. Inside the microcontroller initial frequency feed-back value and the frequency reference value are converted in to same scale and the frequency error is calculated. From the microcontroller continuous PWM signal frequency of 20 KHz is generated. According to the frequency error signal, the duty ratio of the PWM signal output is changed. This output is fed to the IRF740 MOSFET driver circuit in order to control the speed of the prime mover.

2.2 Voltage controlling

The main function of the voltage regulator is to change the generated output terminal voltage of the synchronous generator, according to the voltage variation of system, in order to match the generated voltage with the system voltage before being synchronized. This voltage regulation is achieved by controlling the dc excitation voltage supplied to the rotor of the generator where pwm signal is used as the generated output voltage depends on excitation voltage

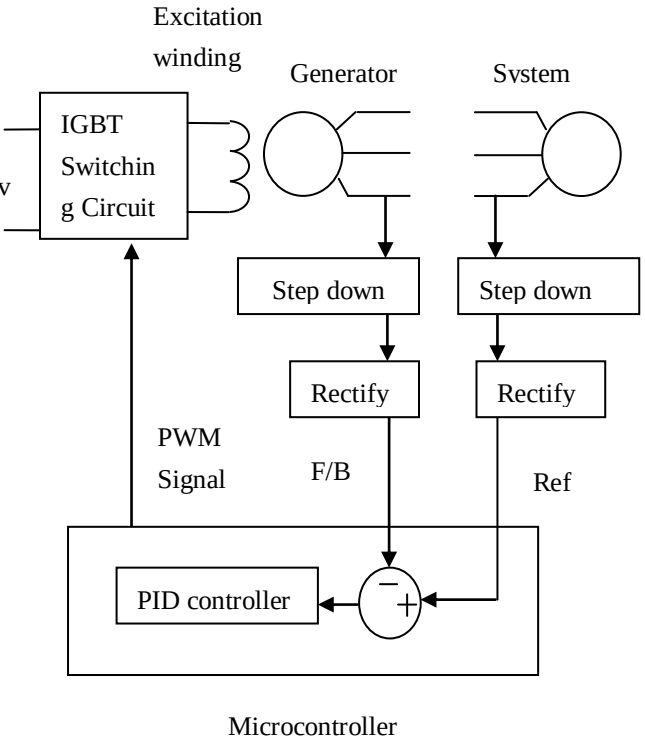

Fig 2: Voltage controlling block diagram

As shown in block diagram here, the terminal voltage of generator is fed to the microcontroller as feedback while system voltage is fed as reference to microcontroller where both signals are step downed & rectified .The duty ratio of the pulse width modulated signal of the microcontroller is varied according to the error signal fed to the embedded PID controller to change the generator output according to the system voltage.

The PWM signal issued by microcontroller is fed to IGBT through a gate driver. Here IRF740 MOSFET is selected according to the excitation current ratings of generator while IR2110 gate driver is selected according to the required voltage input signal of the selected IGBT.18F452 microcontroller is used as it provides the required two PWM outputs.

In this design, the mathematical relation between excitation voltage & output voltage is derived practically by measuring the changes in the voltage generated with the variation of

excitation voltage supply as the theoretical calculations are less reliable. Here, design is to obtain the output PWM signal using an embedded PID controller in microcontroller as it detects the error between a measured process value and a desired set point and outputs a value which determines the reaction to the current error. The relevant tuning parameter Kd, Ki .Kp are designed to observed through Matlab Simulink model using practical data. The voltage controlling algorithm with PID operation is developed.

2.3 In phase point detection

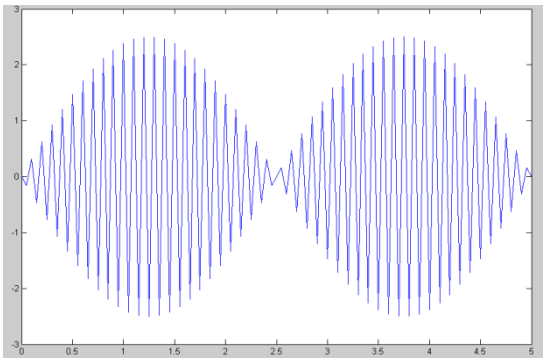

Fig 3: Voltage difference wave

The above voltage signal is analyzed to identify the point where the generator and the grid are in the same phase position. The valley points in the envelop of above signal are the in phase points which are to be detected precisely for the safe synchronizing. However, the envelop cannot be traced directly by demodulators (envelop detectors), since the envelop detected become considerably out of phase from the original signal. Therefore the voltage signal of generator and the system are fed to two zero crossing detectors and their outputs are compared to the find the edge coincidence which is the in phase point.

The same stepped down voltage signals from both generator and system, used in the frequency control circuit, are fed to the two zero crossing detector circuits built in the In Phase Point Detection circuit

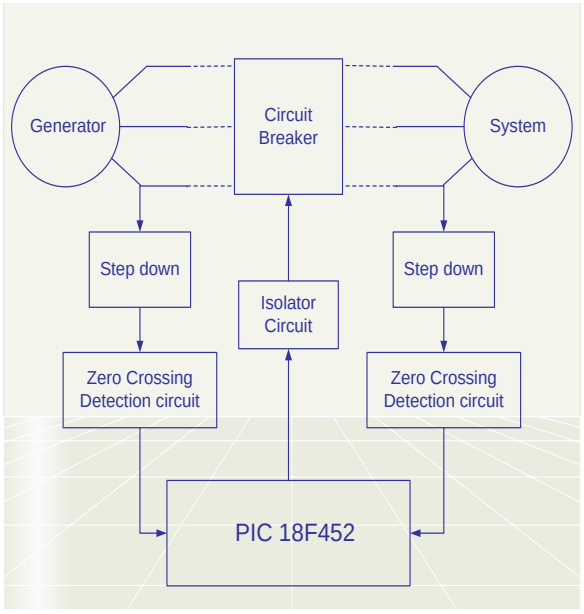

Fig 4: In phase point detecting block diagram

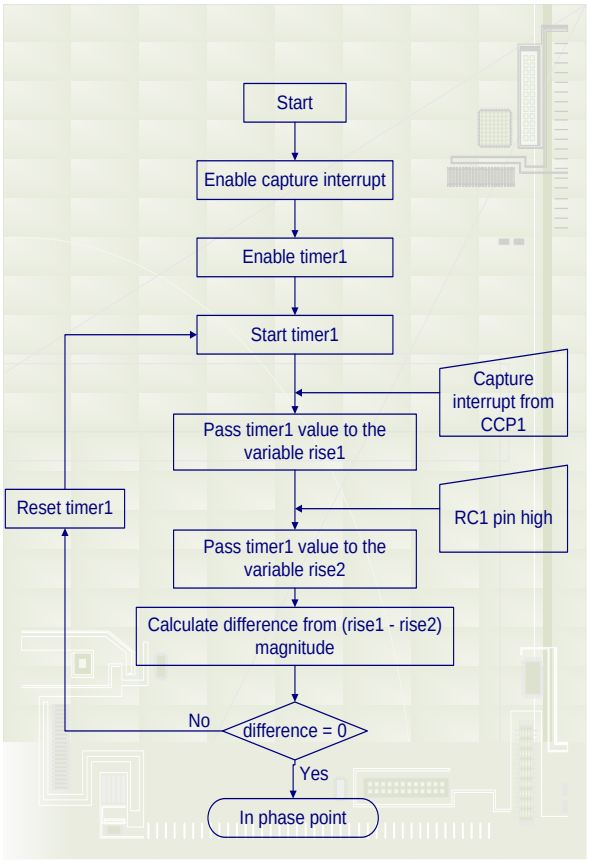

Fig 5: In phase point detection algorithm

2.4 Protection functions

Even the smallest deviation from the operating frequency cause un-repairable damage to the prime mover of the generator. Therefore, protection against frequency deviation is a high priority. Also protection against undesirable voltage deviations is also a must to avoid of occurring harmful effects. [5].

The following protection functions are being implemented in our design. [2].

- Over frequency
- Under frequency
- Over voltage
- Under voltage

3. RESULTS

Circuit breaker operation was achieved at the third successful synchronized instant.

4. CONCLUSION

The outcome of this research is a low cost automatic sync-check relay designed with protection features adhering to existing standards, for a 0.3kVA synchronous generator. When the generator is synchronized with system, *a signal* is issued to operate circuit breaker in order to connect the Distributed Generator to the power system

Since a synchronous generator is used as the DG, the voltage level of generator is controlled by adjusting the DC excitation current supply to the excitation system of generator.

The DC excitation current is controlled by using a PWM signal produced by microcontroller where the PWM signals generated by the microcontroller switch the IGBT across the DC voltage supply of the generator.

Also, a DC motor as the prime mover so that the frequency level of generator is controlled by adjusting the speed of the DC motor. The frequency is controlled by using a PWM signal fed by microcontroller, where the PWM signals generated by the microcontroller switch the IGBT across the armature terminals. Once the necessary conditions for synchronizing is satisfied, by comparing the voltage signal across generator terminals and system terminals in phase point for synchronizing is detected and at the synchronizing point circuit breaker is operated.

5. REFERENCES

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