POWER QUALITY IMPROVEMENT FOR CONVENTIONAL ELECTRONIC LOAD CONTROLLER

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INTRODUCTION:

Various types of ELCs based on controlled (thyristorized) or uncontrolled six-pulse rectifiers with a chopper and an auxiliary load are reported in the literature. These controllers provide effective control but at the cost of distorted voltage and current at the generator terminals, which, in turn, derate the machine. Moreover, the harmonic current injection at generator terminal is not within the prescribed limits by IEEE standards as ($6n \pm 1$) dominant harmonics are present in such system. These harmonics cause additional losses in the system, resonance, and failure of the capacitor bank. In a phase-controlled thyristor-based ELC, the phase angle of back-to-back-connected thyristors is delayed from 0°To 180°as the consumer load is changed from zero to full load. Due to a delay in firing angle, it demands additional reactive power loading and injects harmonics in the system. In the controlled bridge rectifier type of ELC, a firing angle is changed from 0°to 180°for single phase and 0°To 120°for three phases to cover the full range of consumer load from 0% to 100%. In this scheme, six thyristors and their driving circuits are required, and hence, it is complicated, injects harmonics, and demands additional reactive power. Some of ELCs have been proposed that are having quality of the active filter and employs pulse width modulation (PWM) voltage source converter along with the chopper and auxiliary load at dc link to eliminate the harmonics and provide the functions of voltage and frequency regulation. However, such types of controllers make the system costly and complex with complicated control algorithm and simplicity requirement by the isolated system is lost.

Therefore, in this paper, a simple ELC is proposed that regulates the voltage and frequency without any harmonic distortion at the generator terminals. The proposed controller consists of a 24-pulse rectifier, a chopper, and an auxiliary load. In place of six-pulse rectifier, a 24-pulse rectifier-based ELC has negligible harmonic distortion in the generated voltage and current. A comparative study based on simulation is presented and it is also verified experimentally for both types of ELCs.

ELECTRONIC LOAD CONTROLLER:

This control device consists of a speed regulator, an excitation regulator, switches and protection etc. Its main functions are: frequency & voltage stabilization, operation monitoring, relay protection and power distribution. The frequency is stabilized by regulating the extra load. The voltage stabilization is realized through excitation regulation. Therefore the generating unit can be: manual-started, automatically operated, signal-alarm and emergency stopped thus realizing unmanned attendance.

What Is An Asynchronous (Induction) Generator?

The Asynchronous Generator is a very reliable generator that was originally designed as an electric motor but is used as a generator and tends to be comparatively inexpensive and has some mechanical properties that are useful for wind turbines. There is a very important element that makes the asynchronous generator different from the synchronous, that element being the Cage Rotor. In fact one third of the world's electricity consumption is used for running induction motors driving machinery in factories, pumps, fans, compressors, elevators, and other applications where you need to convert electrical energy to mechanical energy. The generator has a simple mechanical configuration with few wear parts. Apart from the special shape of the slipping rotor, the machine neither has slip rings nor brushes. Therefore it requires low maintenance, has a long service life and a robust design.

Induction generators work well with single phase or three phase systems that are interconnected to the utility, as an inducting system requires no governor controls. Induction generators require excitation to operate thus they are ideally suited for interconnection with utility applications. In the single phase operations, it is possible to utilize induction motors as generators to obtain near three phase efficiency by connecting capacitors to the other unused leg of the motor. By doing this the generator will run smoothly operating near one hundred percent (100%) power factor (PF).

The Cage Rotor

The rotor consists of a number of copper or aluminium bars which are connected electrically by aluminium end rings.

The picture above shows how the rotor is provided with an "iron" core, using a stack of thin insulated steel laminations, with holes punched for the conducting aluminium bars. The rotor is placed in the middle of the stator, which in this case, is a 4-pole stator which is directly connected to the three phases of the electrical grid. The rotor automatically adjusts itself to the number of poles.The same stator can therefore be used with a wide varietyof poles.

HOW IT WORKS

Motor Operation

When the current is connected, the machine will start turning like a motor at a speed slightly below the synchronous speed of the rotating magnetic field from the stator. There is a magnetic field that moves relative to the rotor bars which offer very little resistance to the current, since they are short circuited by the end rings. The rotor then develops its own magnetic poles, which in turn become dragged along by the electro-magnetic force from the rotating magnetic field in the stator. The diagram below gives insight on the operation.

When operating in conjunction with a large power grid, a standard single or three phase motor may be used as a generator. In this mode of operation the motor draws its excitation current from the power company grid. The nominal speed of the motor, and consequently that of the turbine, is therefore determined by the line frequency. Driven by the turbine with positive slip, the motor acts as a generator feeding power into the grid. * It is important to note that the operating speed is based on line frequency and the individual slip factor.

Generator Operation

If the speed of the generator is increased above 1500 Rotation per minute (rpm) the resultant effect will be that the rotor will move faster than the rotating magnetic field from the stator. This will then facilitate the induction of a strong current in the rotor. Power supply transferred as an electromagnetic force to the stator can be increased by simply cranking the rotor harder, this will then result in an increase in the amount of electricity converted.

Generator Slip

The speed of the asynchronous generator will vary with the turning force (moment, or torque) applied to it. In practice, the difference between the rotational speed at peak power and at idle is very small, about 1 per cent. This difference in per cent of the synchronous speed is called the generator's slip. Thus a 4-pole generator will run idle at 1500 rpm if it is attached to a grid with a 50 Hz current. If the generator is producing at its maximum power, it will be running at 1515 rpm.

It is a very useful mechanical property that the generator will increase or decrease its speed slightly if the torque varies. This means that there will be less tear and wear on the gearbox. (Lower peak torque). This is one of the most important reasons for using an asynchronous generator rather than a synchronous generator on a wind turbine which is directly connected to the electrical grid

The asynchronous generator requires the stator to be magnetized from the grid before it works.

You can run an asynchronous generator in a standalone system; however, it will require that capacitors which supply the necessary magnetization current be provided. It also requires that there be some left over magnetism in the rotor iron when you start the turbine. Otherwise you will need a battery and power electronics, or a small diesel generator to start the system.

PICO HYDROTURBINE:

In a country like Nepal, rich in hydro power, these systems (Pico Hydro) can be an alternate solution for generating electricity. They are designed to be simple and easy to maintain. They are a special type of turbine generator set with propellers and an alternator mounting at the same frame. The advantage of this system is large discharge and fluctuation in voltage as well as the frequency which can be overcome using the Electronic Load Controller.

SYSTEM CONFIGURATION:

Fig. 1 shows the isolated Pico hydro generating system that consists of an IAG, excitation capacitor, consumer loads, and conventional ELC (six-pulse diode rectifier along with the chopper).

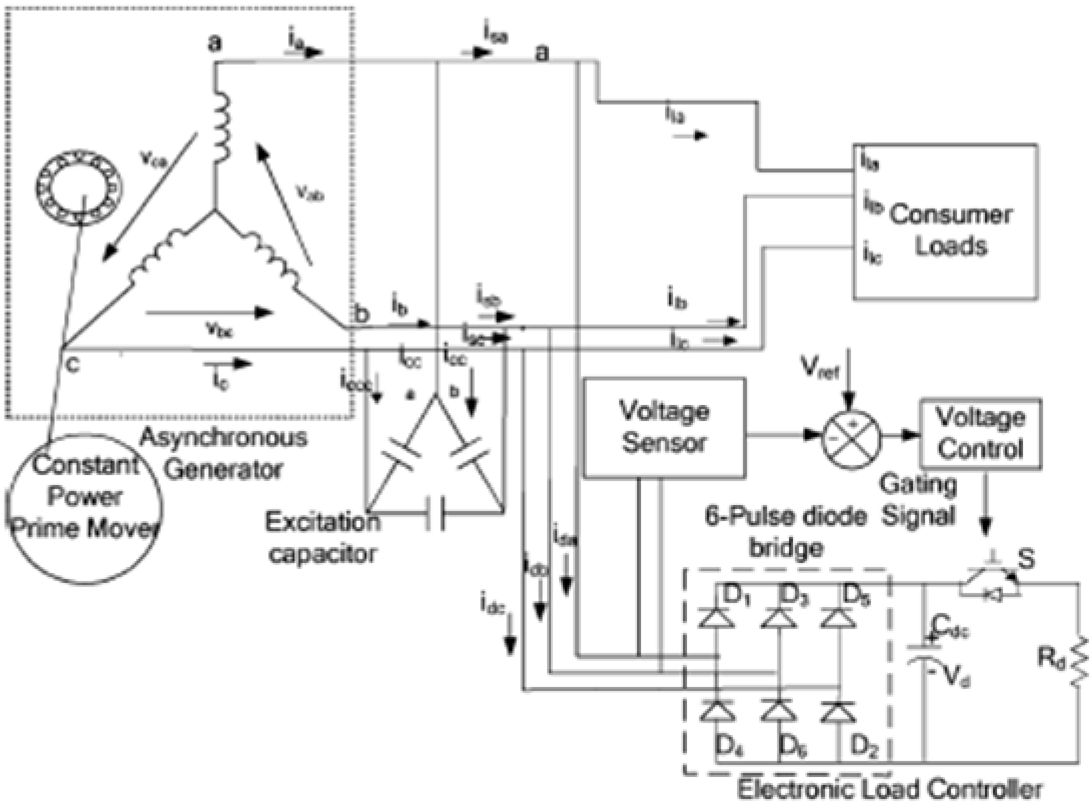

Fig 1. IAG system configuration and control strategy

The diode bridge is used to convert ac terminal voltage of IAG to dc voltage. The output dc voltage has the ripples, which should be filtered, and therefore, a filtering capacitor is used to smoothen the dc voltage. An insulated gate bipolar junction transistor (IGBT) is used as a chopper switch providing the variable dc voltage across the auxiliary load. When the chopper is switched ON, the current flow through its auxiliary load and consumes the difference power (difference of generated power and consumer load power) that results in a constant load on the IAG, and hence, constant voltage and frequency at the varying consumer loads. The duty cycle of the chopper is varied by an analog-controller-based proportional–integral (PI) regulator. The sensed terminal voltage is compared with reference voltage and error signal is processed through PI controller. The output of PI controller is compared with fixed frequency saw tooth wave to generate the varying duty cycle switching signal for the chopper switch.

According to the principle of operation of the system, the suitable value of capacitors is connected to generate rated voltage at desired power. The input power of the IAG is held constant at varying consumer loads. Thus, IAG feeds two loads (consumer load + ELC) in parallel such that the total power is constant

$$P_{gen} = P_{ELC} + P_{load}$$

Where P_{gen} is generated power by the IAG (which should be kept constant), P_{load} is consumed power by consumers, and P_{ELC} is the power absorbed by the ELC.

PROPOSED 24-PULSE ELC CONFIGURATION:

Fig. 2 shows the proposed reduced rating polygon connected Autotransformer fed 24-pulse ac–dc-converter-based ELC for an isolated Pico-hydropower generation applications. This configuration needs one zero-sequence blocking transformer (ZSBT) to ensure independent operation of the two rectifier bridges. It exhibits high impedance to zero-sequence currents, resulting in 120°conduction for each diode and also results in equal current sharing in the output. An inter phase reactor tapped suitably to achieve pulse doubling has been connected at the output of the ZSBT. Two rectifiers output voltages V_{d1} and V_{d2} shown in Fig. 2 are identical but have a phase shift of 30°(Required for achieving 12-pulse operation), and these voltages contain ripple of six times the source frequency. The rectifier output voltage V_d is given by

$$V_d = 0.5(V_{d1} + V_{d2})$$

Similarly, the voltage across inter phase reactor is given by

$$V_m = V_{d1} - V_{d2}$$

where V_m is an ac voltage ripple of 12 times the source frequency appearing across the tapped inter phase reactor, as shown in Fig. 2.

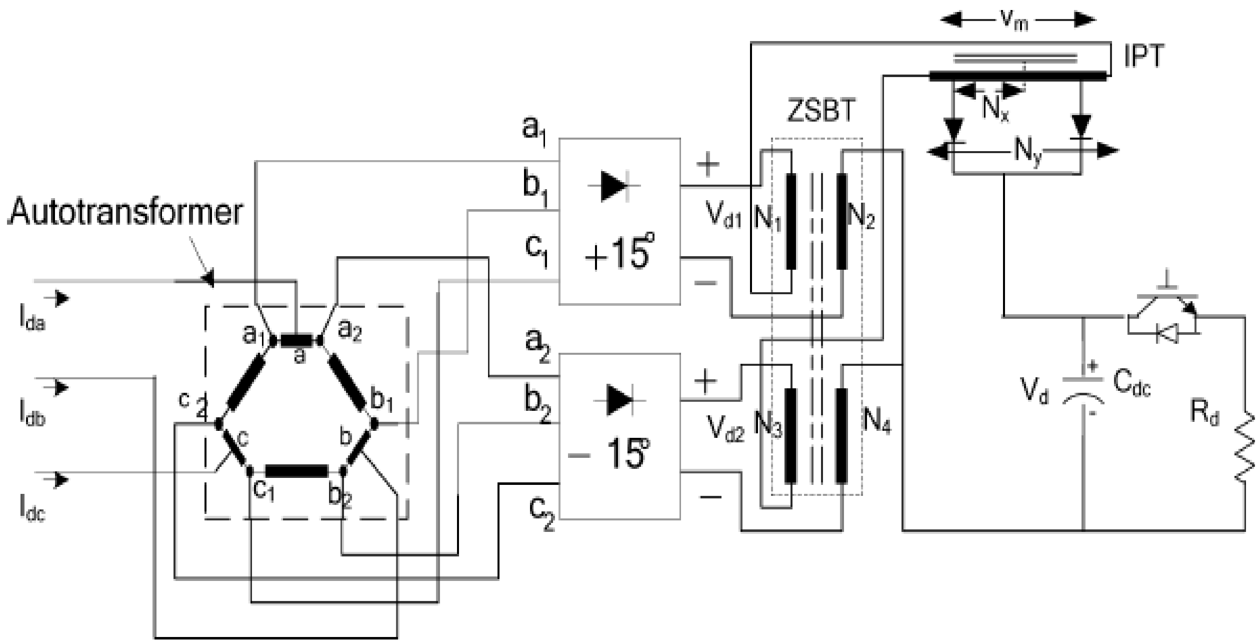

Fig 2. Proposed 24 pulse ELC

This pulse multiplication arrangement for diode bridge rectifiers has been used for desired pulse doubling for line current harmonic reduction. The ZSBT helps in achieving independent operation of the two rectifier bridges, thus eliminating the unwanted conducting sequence of the rectifier diodes. The ZSBT offers very high impedance for zero sequence current components. However, detailed design of the inter phase reactor and ZSBT has been given in and the same procedure is used in this paper. To achieve the 12-pulse rectification, the necessary requirement is the generation of two sets of line voltages of equal magnitude that are 30°out of phase with respect to each other (either ±15°or 0°and 30°). From the generator terminal voltages, two sets of three-phase voltages (phase shifted through +15°and −15°) are produced. The number of turns or voltage fraction across each winding of the autotransformer required for +15°and −15°phase shift is calculated by referring Fig. 3 as follows:

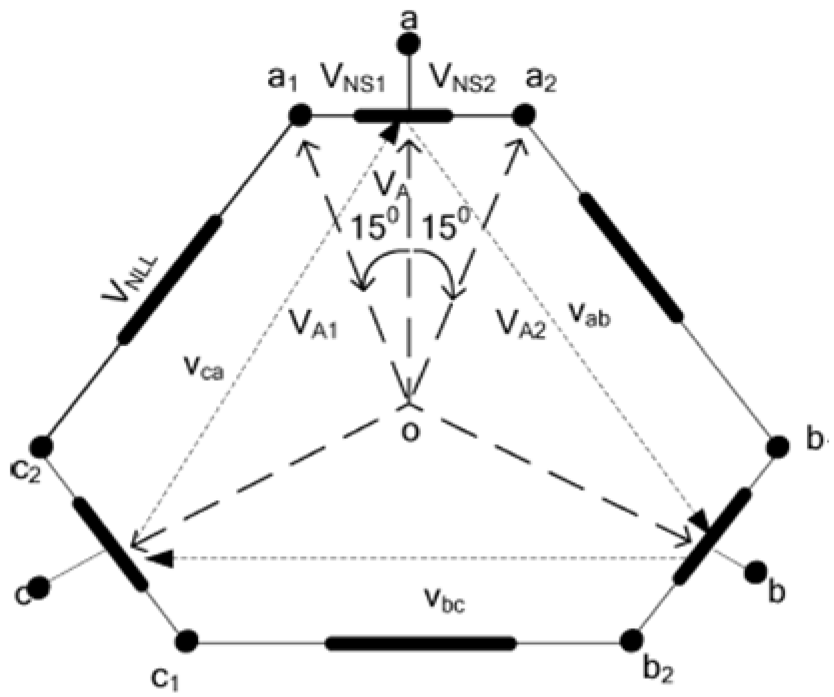

Fig 3. Phasor and Winding diagram of proposed 24 pulse Auto transformer

$$V_{NS1} = V_{NS2}$$

Applying “Sine” rule in triangle “a_1 o a_2” (▼)

$$\frac{V_{A1}}{sin(90)} = \frac{V_{NS1}}{sin(15)} = \frac{V_A}{sin(75)}$$

$$V_{A1} = \frac{sin(15)}{sin(75)} V_A$$

$$V_{NS1} = 0.2679 V_A = 0.2679 \frac{V_{ca}}{\sqrt{3}}$$

$$V_{A1} = \frac{sin(90)}{sin(75)} V_A$$

$$V_{A1} = 1.0352 V_A = 1.0352 \frac{V_{ca}}{\sqrt{3}}$$

$$V_{NLL} = \frac{sin(90)}{sin(45)} V_{A1}$$

$$V_{NLL} = 1.4639 V_A = 1.4639 \frac{V_{ca}}{\sqrt{3}}$$

Where V_{ca} is the line voltage of 415V. The terms V_{NS1} and V_{NS2} are the voltage induced across the short winding and V_{NLL} is the induced voltage across the long winding of polygon connected autotransformer. Detailed hardware design of polygon connected autotransformer, ZSBT, and inter phase transformer (IPT) are given in the Appendix along with the complete design of the proposed 24-pulse ELC.

SIMULATION RESULTS:

NCLUSION:

The ELC designed for IAG and studied by using an auto transformer three phase windings with phase shift of 15 degrees. This can be done for Pico hydro turbine. The proposed 24 pulse ELC practically simulated in MAT Lab.