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Enhancement of Power Quality Using Electronic Load Controller from an Isolated Power Generation

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ABSTRACT

This paper is about Enhancement of power Quality in predominant Electronic load controller by Synchronous generator. The Electronic load controller depends on a six pulse uncontrolled diode bridge rectifier with diodes and IGBT which creates harmonic current and intorsion in the current and terminal voltage of the synchronous generator. The Electronic load controller is also applied to 24-pulse bridge rectifier with diodes and IGBT.A Zig-Zag transformer is used in 24-pulse ac-dc converter to reduce harmonic current to reach the power quality requirements given by IEEE standard-519.Power Quality is improved from six pulse connected rectifier bridge based ELC to the 24-pulse connected rectifier bridge based ELC is done in MATLAB by Simulink and Power System block set tool boxes.

KEYWORDS: *Synchronous Motor (3.125 MVA) Excitation Capacitors, Circuit breaker, PI controller, Electronic load controller, Zig-Zag transformer, IGBT.*

Introduction

The utilization of fossil fuels and their consumption over decades consolidated with a developing concern about contamination of ecosystem have promoted to a lift for renewable power generation. This quickened drive has promoted to a tremendous advance in the field of renewable energy resources. It has likewise brought about a continues tapping of the mini (100KW-1MW), micro (10KW-100KW), Pico hydro (under 10KW) and wind energy is available [1]-[4].In many cases, the generating units need to work at remote areas along these lines, advancement is achieved. In perceptive of this, the synchronous generator with a basic controller for directing the voltage and frequency is most for such devices.

In many research publications are accessible on voltage and frequency controllers for an synchronous generator driven by uncontrolled Pico hydro turbine for single phase [5] as well as three phase control applications [6]-[10].The vast majority of these proposed controllers are accounted as Electronic load controllers (ELC's) that keep up the constant at the generator terminal, to maintain constant voltage and frequency. The estimation of Excitation Capacitor is chosen to produce the rated voltage at the required power. The fundamental guideline of controlling the consistent power at the generator is to utilize an ELC and work in a way so that the aggregate power is constant. On the off chance that there is less demand by the utilizers, then the produced power is consumed by the ELC. The power developed by the ELC is used to do helpful work like water warming, space warming, cooking, battery charging, baking, and so on.

Different sorts of ELCs in the light of controlled (SCR) or uncontrolled six pulse rectifiers with a IGBT and their auxiliary load are accounted in the information[7]-[10].These controllers give efficient control, yet at the cost of intorsion voltage and current at the generated terminals, which, thus ,damage the machine. In addition, the harmonic current infusion at generator terminals is as far as mentioned by IEEE norms as (6n± 1) predominant harmonics are available in such system. These harmonics cause losses in the system, resonance, and deterioration of the capacitor bank. In a phase controlled thyristor based ELC, the phase angle of series connected thyristor is postponed from 0° to 180° as the utilization is changed from zero to full load. Because of delay in firing angle. It require reactive power loading and causes harmonic in the application. In the controlled bridge

Rectifier ELC [9], a firing angle is varied from 0° to 180° for six pulse and 0° to 120° for three phase in order to meet the utilization from 0 to 100 %.Some ELC's has active filter and utilizes pulse width modulation (PWM) with voltage source converter with the IGBT and auxiliary load at DC link to discard these harmonics which are the functions of voltage and frequency regulations .But these control are not only expensive but also have complexity in their algorithm.

Consequently, in this paper, a basic ELC is suggested that controls the voltage and frequency with no harmonic intorsion at these generator terminals. The 24pulse ELC controller comprises of a rectifier, IGBT and an auxiliary load. A 24 pulse rectifier based ELC has negligible harmonic intorsion in the produced voltage and current when compared with 6 pulse Rectifier Bridge. A Comparative simulation is done for both types of 6-pulse and 24-pulse diode bridge rectifier connected ELC.

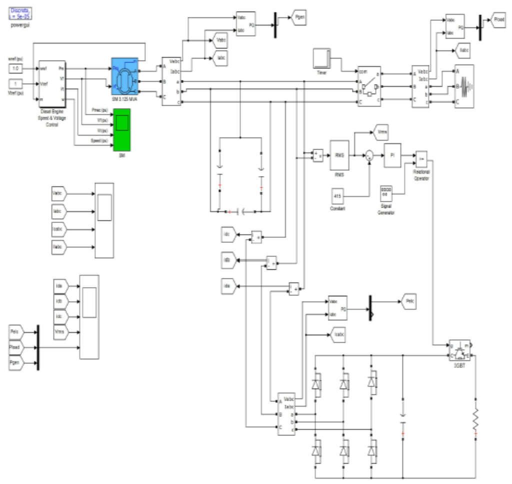

Fig-1 Six pulse Diode Bridge Rectifier connected ELC

II. SYSTEM CONFIGURATION

Fig:-1 demonstrates that generating system comprises of a synchronous generator, excitation capacitor, consumer loads, and ELC (six-pulse and 24 pulse diode rectifier along with the IGBT). The diode bridge converts AC voltage of Synchronous generator to Dc voltage. This controlled Dc voltage still has ripples which ought to be processed so capacitor is utilized to reduce ripples in the DC voltage. IGBT is utilized as a chopper which provides variable DC voltage over the auxiliary load .When the IGBT is on, the current passes through the load and results in constant load on the synchronous generator, thus the constant voltage and frequency can be achieved at the consumer loads .Duty cycle can be varied by PI controller in which detected terminal voltage is compared with the reference voltage and the difference in voltage is given to a PI controller. The output of PI controller is compared with the Saw tooth wave by which variation of duty cycle of IGBT is possible. As per the guideline of operation of the system, a capacitor is selected in order to generate the rated voltage at required power. The input power of synchronous generator will remain constant at different consumer loads. Therefore, synchronous generator serves two loads .i.e.,

Consumer loads and ELC connected in parallel so that the aggregate power remains constant.

Pgen = Pelc+Pload.

Where Pgen is produced power by the synchronous generator,

PLoad is absorbed power by the consumers and

Pelc is the power consumed by the ELC.

III. PROPOSED 24-PULSE ELC CONFIGURATION

This design needs two zero sequence blocking transformer (ZSBT) for individual operation of the two rectifier bridges. It shows high impedance to zero sequence current, which leads to 120° conduction of every diode and has equal current sharing at the output. An Inter phase Transformer (IPT) tapped reasonably to accomplish pulse multiplying has been associated at the output of ZSBT. Two rectifier's output voltages Vd1 and Vd2 are same. However it has the phase shift of 30° to accomplish 12-pulse operation. Further these voltages contain harmonics of six times the source frequency the rectified output voltage Vd is given by

〖V〗d=0.5(V_d1+V_d2) ----- (1)

In the same way, the voltage over inter phase reactor core is

〖V〗m=V_d1-V_d2----- (2)

Where Vm is an ac voltage has ripple of 12 times of the source frequency occurring across tapped Inter phase reactor .This pulse augmentation action has been utilized for required pulse doubling to reduce harmonic reduction. The ZSBT has high impedance for zero sequence currents. The definite design of the inter phase reactor and ZSBT has given in and the same method is utilized as a part of this paper to accomplish 12-pulse operation, generation of two sets of line voltages of equivalent value and are 30° out of phase with each other either + 15° or 0° and 30°.From the generator terminal voltages two arrangements of 3-phase voltages in phase shift of + 15° and -15° is created. The number of turns across every winding of Zig-Zag transformer required for +15° and -15° phase shift is computed from fig-2 as

〖V〗_NS1=V_NS2----- (3)

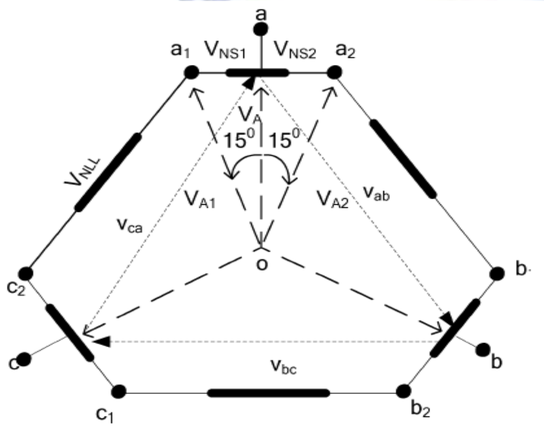

Fig-2 Phasor diagram of 24 pulse auto transformer connected ELC

Applying Sine rule for the triangle "a1oa2"

$$\frac{V_{A1}}{\sin 90^\circ}=\frac{V_{NS1}}{\sin 15^\circ}=\frac{V_A}{\sin 75^\circ} \text{----- (4)}$$

$$V_{NS1}=\frac{\sin 15^\circ}{\sin 75^\circ} * V_A$$

$$V_{NS1}=0.2679*V_A=0.2679*(\frac{V_{ca}}{\sqrt{3}}) \text{ ----- (5)}$$

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

$$V_{A1}=1.0352*V_A=1.0352*(\frac{V_{ca}}{\sqrt{3}}) \text{ ----- (6)}$$

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

$$V_{NLL}=1.4639*V_A=1.4639*(\frac{V_{ca}}{\sqrt{3}}) \text{ ----- (7)}$$

IV. MATLAB BASED MODELLING

A 7.5KW, 415V, 50Hz synchronous machine is utilized for power generation and the ELC is designed from power electronic blocks comprising of diode rectifier, IGBT, with a resistive load and ZIG-ZAG transformer is utilized to obtain the required phase shift of 24-pulse operation. Simulation is done in MATLAB model of 8.1.0.604 (R2013a) at discrete value of 50E-5.Simulation is done in 6 and 24-pulse based ELC is mentioned in the simulation result.

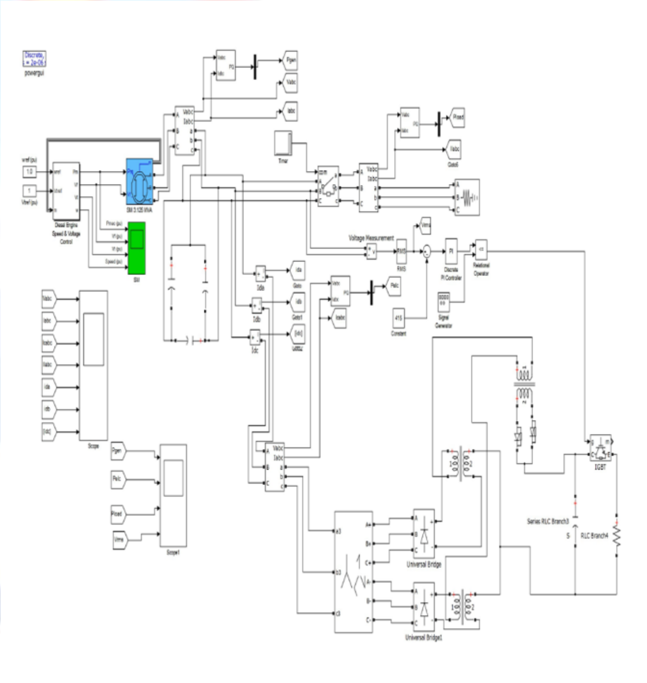

Fig-3: 24-pulse Diode Bridge Rectifier Connected ELC

V. SIMULATION RESULT

A.Execution of six-pulse diode bridge ELC:

Fig-4 demonstrates the plot of synchronous motor when connected with six pulse diode ELC. Fig-5 demonstrates the variant transient waveforms of synchronous generator with six-pulse diode bridge ELC rectifier .The capacitor value is chosen to produce RMS voltage of 415V at rated load of 7.5KW.When the consumer loads are absent then ELC delivers 7.5KW to the auxiliary load .After 2 sec, the current passing through the ELC is decreased due to addition of consumer load of 5 KW. Again after 2.3 sec the consumer load is taken to off state then the current through the ELC is increased. The intorsion in the generator voltage and current is observed under six pulse diode rectifier based ELC. In the same way 24-pulse bridge rectifier ELC is shown in Fig-7. The harmonic spectrum can be observed during zero load condition when ELC fetch maximum power. Because of non-linear behavior of this ELC, the current has total harmonic distortion (THD) of 37.13% which intorsion the THD voltage of 8.3% while THD current of 11.33% at the generator terminals.

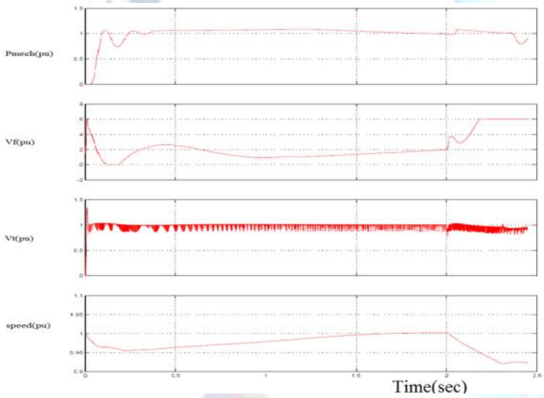

Fig-4: Simulation plot at Synchronous Motor with six pulse Diode Bridge connected ELC

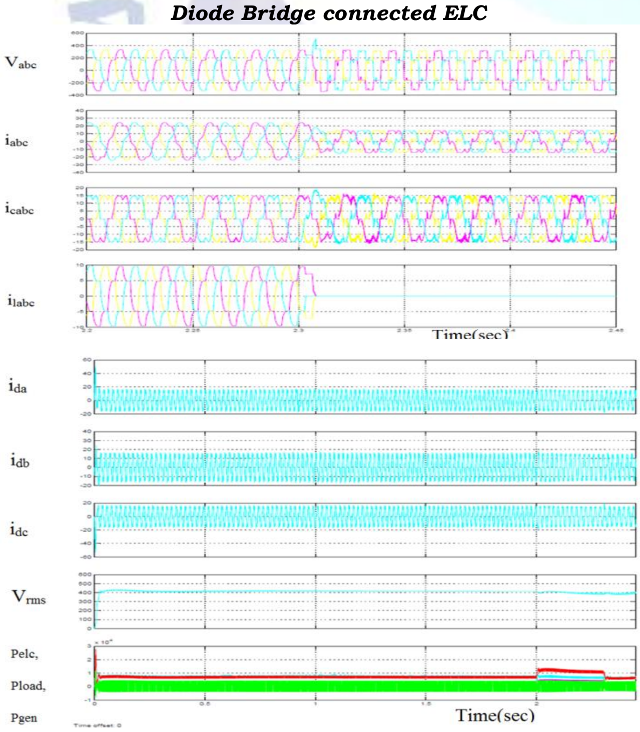

Fig-5: Simulation Waveforms due to six pulse diode bridge ELC

B. Execution of 24-pulse diode bridge ELC:

Fig-6 shows the plot of synchronous motor when connected with 24-pulse diode bridge ELC. Fig-7(a,b), demonstrates the transient waveforms of Synchronous generator utilizing 24-pulse rectifier bridge ELC.ELC regulates the constant power at the generator terminal with the change in the consumer loads .Therefore the voltage and frequency are at constant magnitude and intorsion in the voltage and current has less harmonics when compared with six pulse diode bridge ELC. The intorsion in the voltage and current of 24-pulse diode bridge ELC is very less that to 0.42%-0.47%.

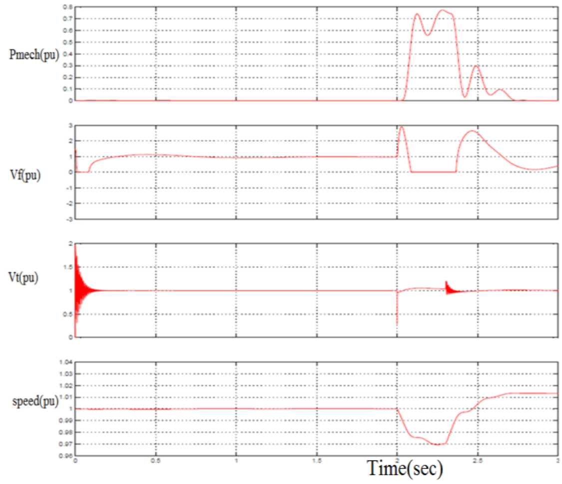

Fig-6: Simulation waveform at synchronous motor with 24 –pulse connected diode bridge ELC

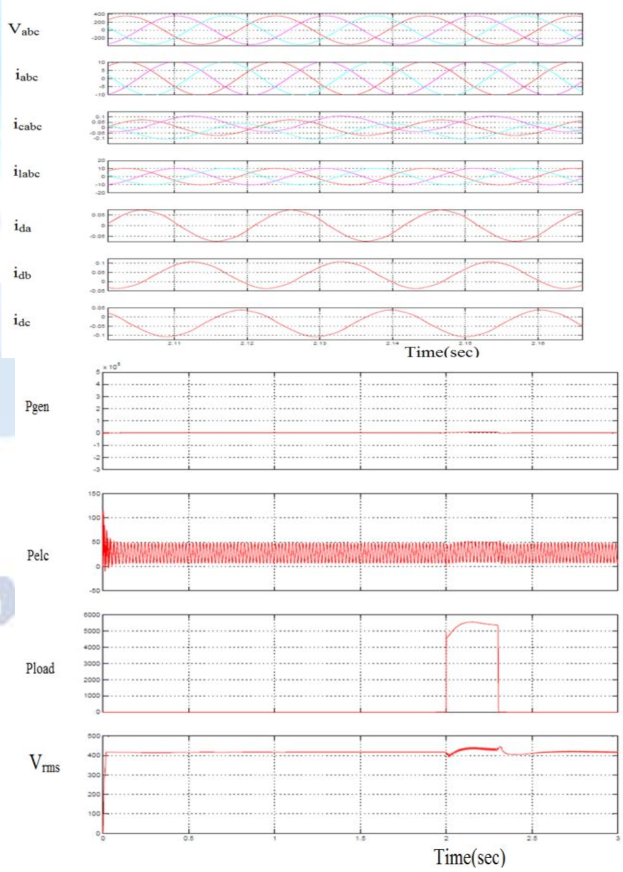

Fig-7: Simulated Waveforms Due to 24-pulse diode bridge ELC

VI. CONCLUSION

The ELC has been acknowledged utilizing 24-pulse converter and a chopper (IGBT).A similar study of both sorts of ELC's i.e., six pulse and 24-pulse diode bridge ELC has been illustrated based on the simulation using MATLAB software. The 24-pulse ELC has enhanced execution in voltage and frequency of synchronous generator with less harmonic intorsions in the produced voltage and currents at different consumer loads.

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