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Solar Car-Main Grid Interface Model Using Phase Lock Loop

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Abstract: **-- Renewable resources of energy for generation of electricity are the common trend in today's world. Of these, solar energy occupies a paramount position as a source of abundant and continuous renewable energy with a variety of applications. Solar cars are one of the most important inventions. The paper aims at making use of the surplus solar energy stored in the batteries of the solar cars. The specific strategy is to prepare a model of the interface between the main grid and a fleet of ten to fifteen solar cars. This interface employs phase locked loop which locks the phase of the signals coming from the batteries of the solar cars with that from the main grid. The paper provides simulation result of the interface control model.**

Keywords**:—phase lock loop, loop filter, voltage controlled oscillator, XOR detector**

I. INTRODUCTION

A Phase Locked Loop (PLL) is an electronic circuit which is a simple control system consisting of a voltage or current driven oscillator designed to lock the phase of an input signal with the help of a reference signal [1]. Since a PLL is quite versatile and is flexible enough to make use of any component as per the requirements, thus it is used in various applications of electrical technology. A basic phase lock loop consists of a phase detector, a loop filter and a voltage controlled oscillator. The purpose of phase locking is to evaluate the difference between phase angle of the input signal and output signal generated by the voltage control oscillator [2]. In the proposed model the phase lock loop works under two modes. In the first mode, there are two voltage sources that are the input to the XOR phase detector. One source is the main grid which supplies a single phase AC voltage at the substation end. The other is the solar cars' batteries which is the inverter based source that does not generate power at the grid frequency and thus need an inverter. In the second mode, the inputs to the XOR phase detector are now the output generated by the voltage controlled oscillator and the AC supply from the main grid.

The proposed model of the interface control system aims at supplying surplus solar energy from the solar cars to the main grid. It serves many advantages. Firstly the employment of solar energy makes the system eco-friendly and pollution –free. Secondly, the drivers of the solar cars can earn money by

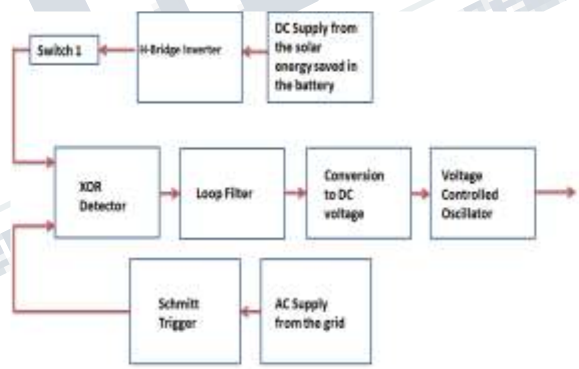

Fig1(a): Control Model when switch 1 is ON (first cycle)

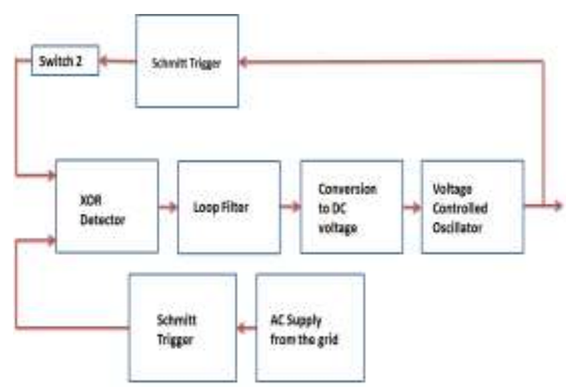

Fig1(b): Control Model when switch 2 is ON (after the first cycle)

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Selling the surplus energy to the main grid. In this way, this efficient interface system serves to be economic as well as an ideal model towards sustainable development. The interface control system can be installed nearby a substation of a large University or an organization. This system can be called a solar car-grid station which takes in the solar energy from the batteries of the solar cars every day and the sells it to the main grid through the substation. The solar cars will operate in the university or an organization throughout the working hours and at the end of each day the surplus solar energy will be given to the station.
The paper is organized as follows: Section II provides the methodology of the simulated model which describes the software used and the interpretation of the results. Section III gives the reference of the necessary data collected for the simulation. Section IV gives a detailed study of the simulation of each of the components of the system. Section V gives the results of the simulation. Conclusion is provided in section VI.

II. METHODOLOGY

The interface model was developed in PSIM software and the simulation results were provided. PSIM 10 32-bit software is used to realize the block diagram and simulate the results. Some components of the block diagram were present as examples in this software which were modified as per the requirements. The two modes of the model are shown in Fig 1(a) and Fig 1(b).

III. DATA COLLECTION

The data regarding the nature of the voltage signal coming from the main grid was collected from BSES Rajdhani Power Limited. It was found that a single phase sinusoidal sine AC supply with a peak voltage value of 325.26V is distributed at 50Hz.

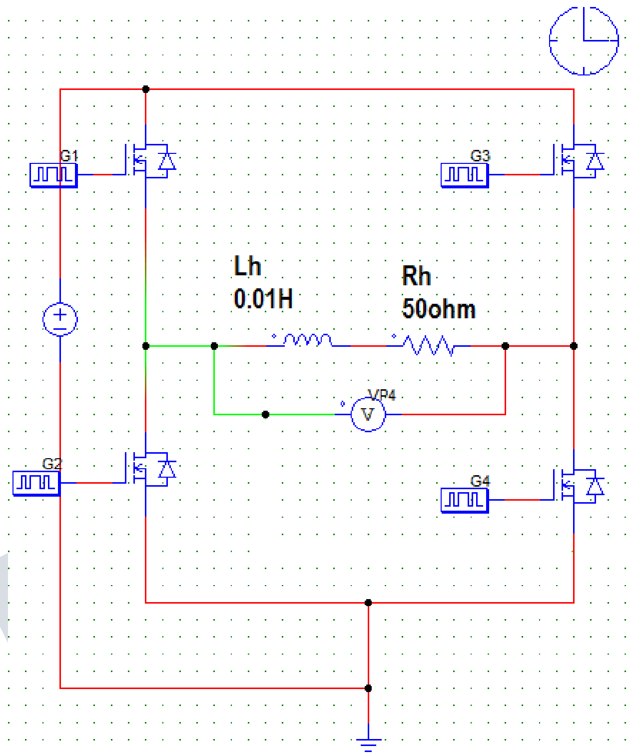

Fig 2: H-Bridge Inverter

S.No.	Name of Component	Values
1.	Inductance (Lh)	0.01H
2.	Resistance (Rh)	50Ω

Table 1: Values of components used in H-Bridge Inverter

IV. SIMULATION

There are two modes of operation. Firstly the 12V DC supply stored in the batteries of the solar car is given a boost to a 325.26V. Then this 325.26V DC supply is the input to the H-Bridge inverter. This type of inverter is widely used and has found many applications in high power rating circuits [3]. The simulation result of the H-Bridge inverter is shown in Fig 7. The values of inductance and resistance used in the H-Bridge inverter are shown in Table 1 and represented by Lh and Rh respectively. The total time of simulation is taken as 0.04sec. The circuit model of an H-Bridge inverter is shown in Fig 2.At the main grid end, the AC sinusoidal voltage is fed to a Schmitt trigger. It is like a comparator with a positive feedback [4]. It gives a high output when the input is higher than a threshold value and a low value when the input is of higher value than the threshold value [4]. However, instead of a comparator, Schmitt trigger is used. It is so because unlike a comparator which has one switching threshold, Schmitt trigger has different threshold values for the negative and positive edge input signals [5]. The Schmitt trigger in the model consists of a comparator which gives high value when the non-inverting input is higher than the inverting input.

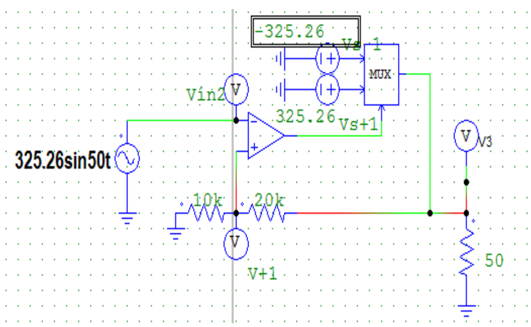

Fig 3: Schmitt Trigger

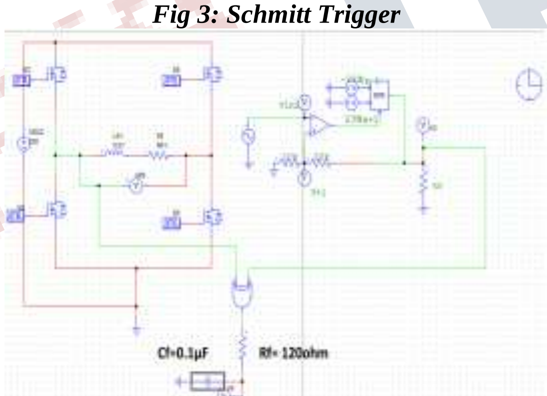

Fig 4: XOR detector along with a filter

Table 2: Values used in the filter

S.No.	Name of Component	Values
1.	Resistance (Rf)	120Ω
2.	Capacitance (Cf)	0.1µF

When the positive input is lower, the output is zero. When the two inputs are equal, the output remains unchanged. Once the output is obtained, it is then fed to the XOR detector. The XOR detector has an advantage that the loop gain does not depend on the amplitude of the input signal [6]. Also, the response can have a larger linear range than a sinusoidal mixer [6].

The signal obtained is then fed to the low pass RC filter with values specified in Table 2. Once the output from the XOR detector is fed to a low pass filter, a voltage signal of low frequency is generated. The generated signal has peak value 1 when high and 0 when low. Thus it needs to amplified 325.26V (i.e., the peak value of the desired voltage). This is done with the help of a circuit consisting of a diode and a not gate along with a gain of 325.26V. Thus now we obtain a DC voltage of 325.26V. It is then suitable to be fed to a voltage controlled oscillator. The oscillator generates the output signal and is actually driven by the output of the low pass filter [7]. It gives a measure of variations of the phase of the input and gives the output with a frequency equal to the input signal [8]. The deviation of the error signal from zero is because of any change in the phase angle (or frequency) of the input signal [9].
After the completion of one cycle, switch 1 is OFF manually and switch 2 is ON manually as shown in Fig 1(b). Now the output from the voltage controlled oscillator is fed to the Schmitt Trigger again so as to obtain a rectangular pulse wave suitable to be fed to the XOR detector. Now this voltage signal along with the signal coming from the Schmitt trigger act as the input to the XOR detector. The process will continue till the desired output is obtained. The desired output obtained is the sinusoidal sine wave of peak value 325.26V with a frequency of 50Hz. This is same as that supplied by the main grid. Hence the signal obtained can now be sold to main grid. The circuit is shown in figure 6.

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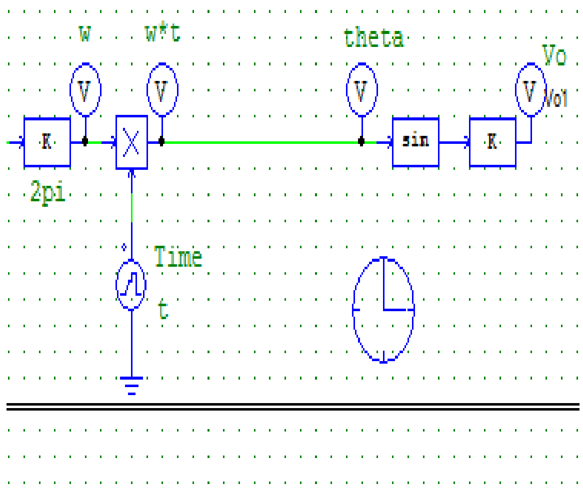

Fig 5: Voltage controlled Oscillator with gain as 56

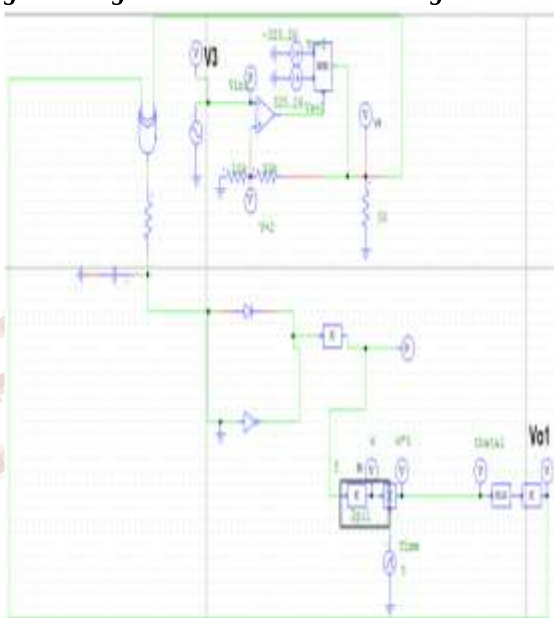

Fig 6: Complete PLL with Vo1 as the output

V. SIMULATION RESULTS

The following are the simulation results of the circuit elements of the phase lock loop.

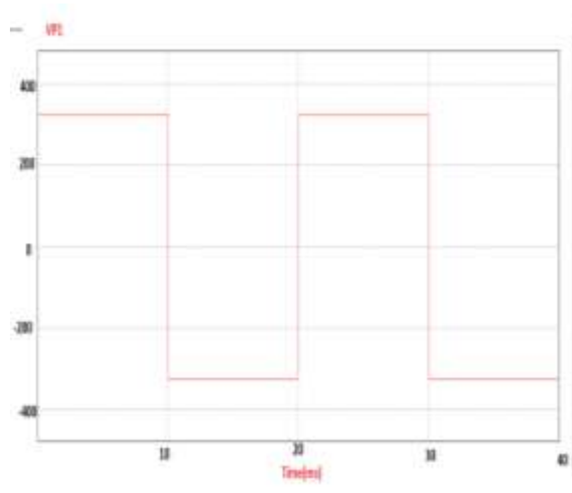

Fig 7: Output of the H- Bridge Inverter

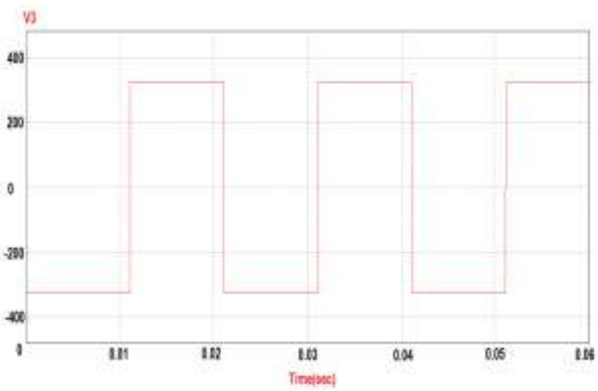

Fig 8: Output of the Schmitt Trigger

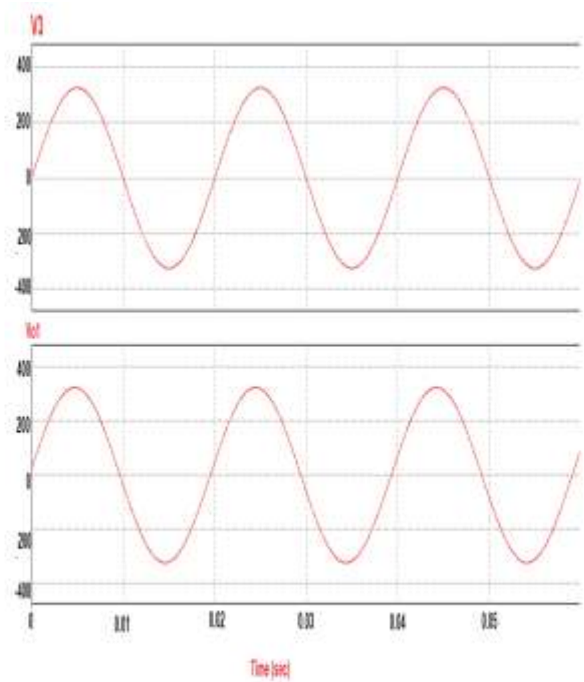

Fig 9: Final Output Vo1 in phase with input V3

VI. CONCLUSION

The utility of solar energy is abundant and is very eco-friendly. Apart from being eco-friendly, this model presentation can be economical to the drivers and it can be an addition to their income.

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