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Integration of Micro Grid System using 3-Level Inverter

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Abstract: A hybrid power system modeled in Matlab/ Simulink environment is presented in this study. This model includes a hybrid system consisting of wind and solar panels and it is connected to the smart grid through a 6-switched 3-level inverter. A 6-switched 3-level inverter is preferred in this study as an inverter due to its success in minimizing the harmonics. In order to achieve the lower current harmonic, an LCL filter is widely utilized due to its superior filtering performance. Passive and active damping control are studied to solve the resonant problem appearing in an LCL filter, active damping control overcomes the weakness of power loss existing in the passive damping method, thus it gradually becomes one of research focus. The system fed the receivers by generating electricity energy and sent the generated excess energy to the grid (grid) on favorable conditions, that is, when wind and/or sun are sufficient for energy production. The receivers are fed by the grid on unfavorable conditions. By means of analyzing the performance of the system, it is determined that the system is stable.

Key Words: 6–Switched 3-Level Inverter, Hybrid Power System, Smart Grid, Solar Panel, Wind Turbine.

I. INTRODUCTION

Day to day life population was gradually increased then resources also needed more and towards technology also increased that the same time we have utilize power sources carefully. The nature having a few fossil-based energy resources are available this situation caused by the damage to the environment then the energy sources and the fact that they will be expanded over time have made and it was necessary to back to reproduce energy resources such as wind and solar energies. One of renewable energy has wind energy which was inexhaustible. The wind energy is environment-friendly. And it was free of cost that means getting from nature [1].The wind energy was gradually developing [2], the cheapest and it was widely-used energy resource. However, it had an interrupted and stochastic structure inherently[3,4]. So in terms of energy sustainability it having constituted a risk and represented a problem in terms of system stability. On the other hand, solar energy was radiation energy. The intensity of solar energy outside the Earth's atmosphere is 1370 W / m² and it was varied between the values of 0-1100 W/m2 on the Earth. The world was much more when even a small portion of this energy reached than the existing energy consumption of mankind [5]. The hybrid system was a system in which more than one energy sources were used. Therefore, different properties could form a hybrid system when even the energies with structurally. For example, in this study it was possible to form a hybrid system consisting of wind turbines and solar panels. When the wind speed was abundant, the wind turbines could be generate energy whatever it was day or night. However, in certain time periods solar panels could be generate energy depending on the sunshine time span.

In addition, these two units could feed the receivers by generating energy. However, the receivers were deprived of energy when the wind speed and/or the sun were insufficient. In this case, the smart grids were engaged and the receivers were fed from the grid. Thus, the regularity of energy was ensured for the receivers without any interruption. The demand for smart grids was increased now a days. The highlighted reasons behind this demand were as follows: the detailed price information in the smart grid; the opportunity has chosen to among many programs, prices and options; in the system in addition the fact was that different distributed generation resources were added to the central system; and it would occur the development of new electricity market which had taken into report the technological developments and different production options; the fact that the power quality was a priority in terms of smart grids; the increase of the productivity and efficiency along with the integration of artificial intelligence of the grid into asset management applications; taking precautions in advance for preventing the failure; and to minimizing the effects of failure and ensuring the regularity of communication; the fact that the system was continued to operated by recovering itself rapidly under circumstances those were natural disasters and attack [6].

A considerable number of micro hybrid power systems when the performed literature studies, different from each other, and smart grid coordination were observed [7-22]. The excellence transformation models were used in most of these models. However, the aim of this study was to use a transformation model with a various topologis for the integration of the micro hybrid power system into a smart grid. This transformation model was a 6-switched 3-level inverter which had an alternative topology to multilevel inverters. By using this model, it is aimed to decrease the amount of oscillations in the system substantially and to increase the stability level of the entire system.

II. 6-SWITCHED 3-LEVEL INVERTER TECHNOLOGY

The multi-level inverter topologies were recently these were alternate to the topologies. The six units of IGBT semiconductor switches and double wound coils were used in this inverter topology, this was used for each output lead of the inverter. The 6-switched 3-level inverter was shown in Fig.1. The multi-level output voltages were produced these topology along the DC source was applied to its input and three-phase split-wound double wound coils connected to each output. In this S_1 and S_2 were switches and both S_1 and S_2 switches were in transmission or cut-off, a voltage of + ½ VDC and VDC was acquired from the VAN. Here VAN was the output voltage terminal. When S_1 switch was in cut-off and S_2 switch was in transmission, then that time VAN was associated to the negative DC bus bar and that time no voltage was generated. The + VDC voltage was generated when S_1 switch was in transmission region and S_2 switch was in cut-off region, then VAN was connected to the positive DC busbar [23]. The mentioned cases are shown in Fig.2.

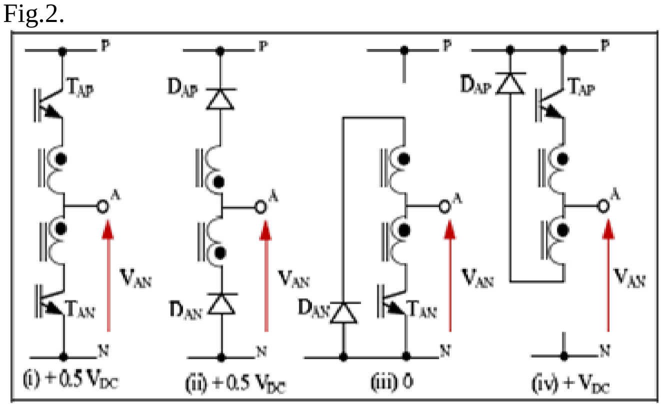

Fig.1. 6-switched 3-level inverter and switching status of one brand of.

The relationship between the A, B and C voltages are given when we regared the inverter as three phased and balanced in Eq.1

$$V_{A0}(t) + V_{B0}(t) + V_{C0}(t) = 0 \quad (1)$$

By using the analog or digital control unit when the effect of the dead-time protection was not suppressed. At inverter outputs the dead-time was reduced phase voltages and serious distortions was occurred. The 6-switched 3-level inverter topology did eliminated the dead-time protection, and also allows for the simultaneous transmission of the upper and lower keys in DGM switching layouts. Thanks to this unique feature, output switching frequency was doubled when the dead-time was effected disappear, an additional midpoint voltage was generated and the effective. Thus, harmonic distortion in the output waveform is largely eliminated by rising up to level 3 voltage and doubling the effective switching frequency. The structurally asynchronous motor speed was control of the 6- switched 3-level inverter [23] and its being allocated for the RL load [23] . It can be understood by the low Total Harmonic Distortion (THD) output obtained which was redacted the harmonic distortions significantly.

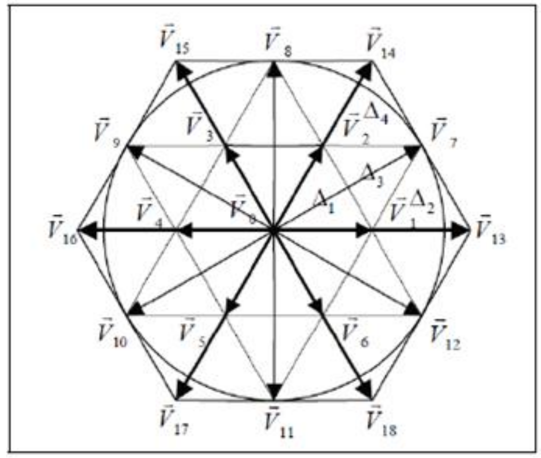

Fig.2. Space vectors of 6-switched 3-level inverter.

TABLE I: Switching Status For Each Vector

$\vec{V}_0$ [00 00 00] [00 00 11] [00 11 00] [00 11 11] [11 00 00] [11 00 11] [11 11 00] [11 11 11] [01 01 01] [10 10 10] [$S_1S_2S_3S_4S_5S_6$] Switch on :1 Switch off: 0	$\vec{V}_1$ [00 01 01] [11 01 01] [10 00 00] [10 00 11] [10 11 00] [10 11 11]	$\vec{V}_2$ [10 10 00] [10 10 11] [00 00 01] [00 11 01] [11 00 01] [11 11 01]	$\vec{V}_3$ [01 00 01] [01 11 01] [00 10 00] [00 10 11] [11 10 00] [11 10 11]	$\vec{V}_4$ [00 10 10] [11 10 10] [01 00 00] [01 00 11] [01 11 00] [01 11 11]	$\vec{V}_5$ [01 01 00] [01 01 11] [00 00 10] [00 11 10] [11 00 10] [11 11 10]	$\vec{V}_6$ [10 00 10] [10 11 10] [00 01 00] [00 01 11] [11 01 00] [11 01 11]
	$\vec{V}_7$ [10 00 01] [10 11 01]	$\vec{V}_8$ [00 10 01] [11 10 01]	$\vec{V}_9$ [01 10 00] [01 10 11]	$\vec{V}_{10}$ [01 00 10] [01 11 10]	$\vec{V}_1$ [00 01 10] [11 01 10]	$\vec{V}_{12}$ [10 01 00] [10 01 11]
	$\vec{V}_{13}$ [10 01 01]	$\vec{V}_{14}$ [10 10 01]	$\vec{V}_{15}$ [01 10 01]	$\vec{V}_{16}$ [01 10 10]	$\vec{V}_{17}$ [01 01 10]	$\vec{V}_{18}$ [10 01 10]

If the space vector voltage was expressed in terms of α and β planes which was having 900 phase difference:

$$\vec{V}(t) = V_\alpha(t) + jV_\beta(t) \quad (2)$$

If the three phased variables were transformed into α and β variables:

$$\begin{bmatrix} V_\alpha(t) \\ V_\beta(t) \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{A0}(t) \\ V_{B0}(t) \\ V_{C0}(t) \end{bmatrix} \quad (3)$$

If Eq.3 was transferred into Eq.2:

$$\vec{V}(t) = \frac{2}{3}\left(V_{A0}(t)e^{j0} + V_{B0}(t)e^{j2\pi/3} + V_{C0}(t)e^{j4\pi}\right. \quad (4)$$

In this study, due to the success of the asynchronous motor and RL load it was aimed to use a 6-switched 3-level inverter as an inverter and, therefore, to significantly reducing the harmonics it was also aimed to obtain system stability.

III. PROPOSED SUSTAINABLE MICROGRID ARCHITECTURE

The proposed hybrid simulation model was designed in Matlab Simulink and consisted of 3 basic parts. In the first part, DC voltage was obtained, which was made from the wind turbine and solar panel. In the second part, the DC voltage value obtained in the first part and it was increased to 220V DC. In the third part, the 6- switched 3-level inverter generated 220V AC 3-phase grid voltage and fed the load. The simulation models and outputs belonging to each section are shown below Fig.3.

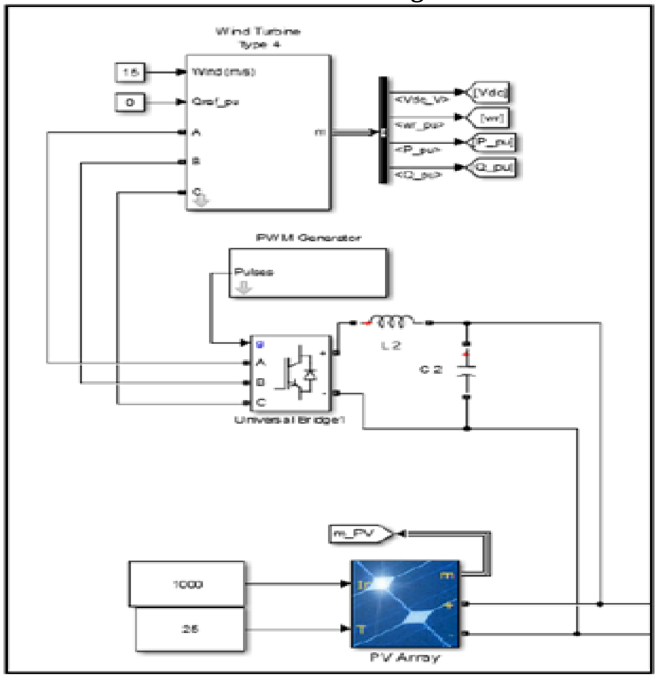

Fig.3. Micro hybrid power source consist of wind turbine and PV panel.

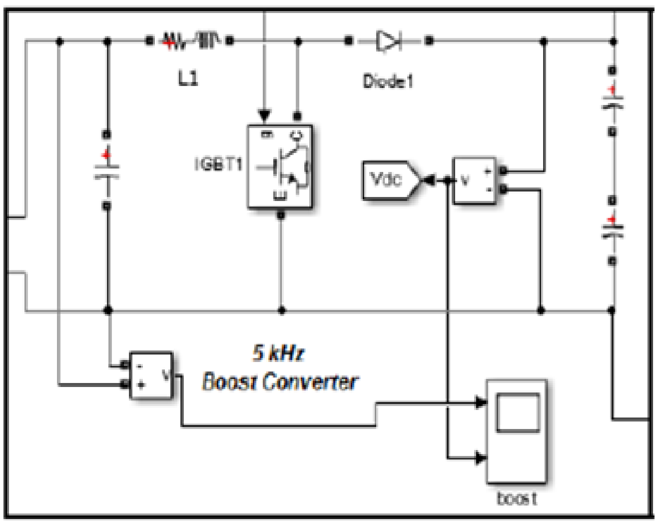

Fig.4. Boost converter.

The first part of the proposed design was shown in Fig.4. In a parallel way the wind turbine and the solar panel were connected. For the wind turbine, the wind speed had undertaken to be constantly 15 m / s, and Qref_pu value was taken as 0. For the solar panel, the radiation was obtained to be 1000w/m2 and the temperature was obtained to be 25 °C. In other words, a micro modeling was done with reference to the ideal conditions of the hybrid system. The boost converter simulation model was shown in Fig.4. In this study, instead of using a transformer at the output of the inverter a boost converter was used at the output of the DC source. The distortions that would be caused by the transformer and perform an operation of a clean/smooth voltage boost. 75 V DC voltage was increased up to 300 V DC in this study. The comparison the input and output voltages of the boost converter was shown in Fig.5.

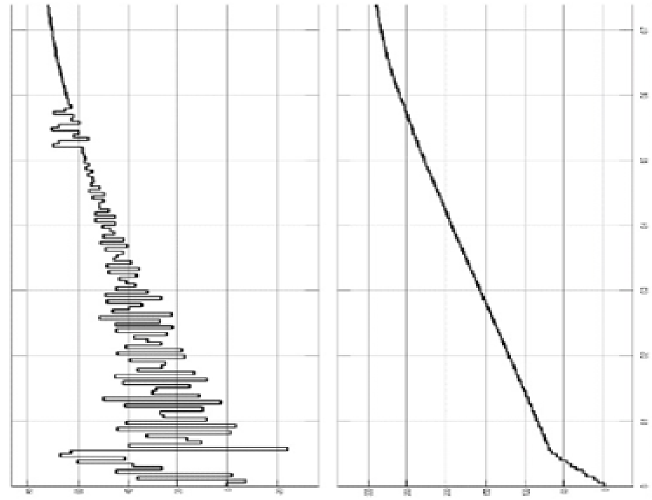

Fig.5. Input and output voltage of boost converter.

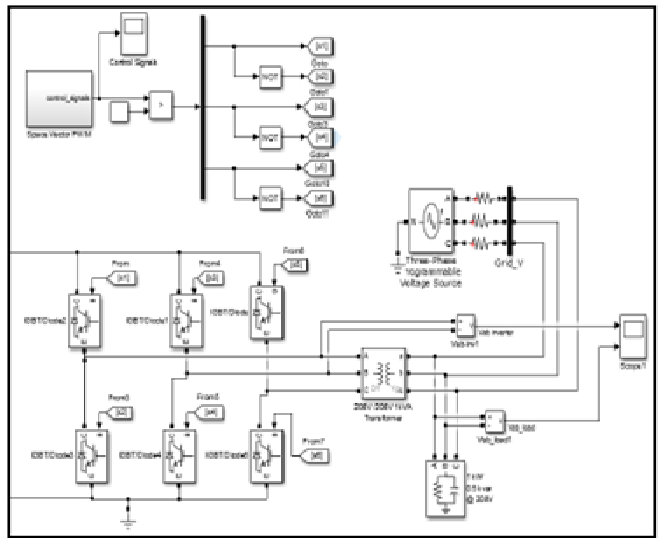

Fig.6. 6-switched 3-level inverter, SVPWM and 1kW Load Simulation Model.

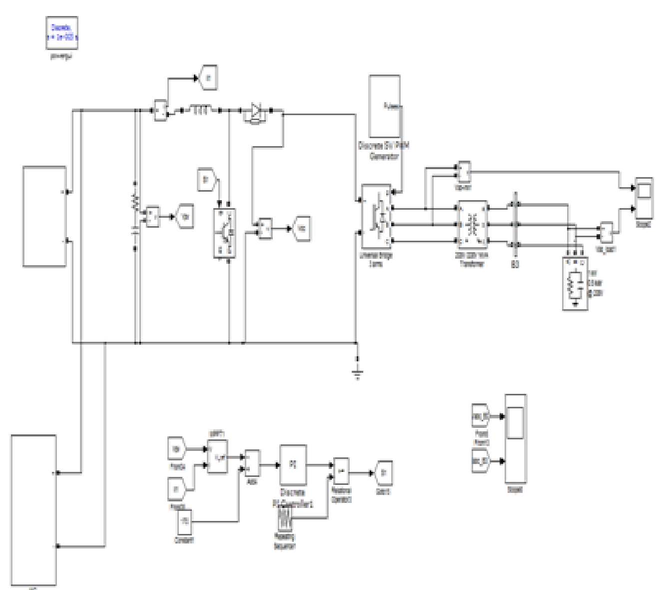

Fig.7. Proposed micro grid hybrid model.

The 6-switched 3-level inverter, SVPWM and load model were shown in Fig.6. The load side of the transformer was used for insulation purposes. Here, the micro grid application fed the grid as it was an on grid application. it would be adequate for the micro system. The system is not connected to the grid when in the case of the interruption of the grid, when the grid as 220 V AC, then the 300V DC access value reaching to the inverter sent out from. This obtained voltage was isolated by a transformer and transferred to the load in a 3-phase manner. The model of the system proposed here was shown in Fig.7 with all its parts. The 3-phase output values were obtained from the output of the inverter were shown in Fig.8. In addition, the voltage going out from the inverter and transferred to the load was shown on the same plot in Fig.9. The Fast Fourier Transform (FFT) analysis of harmonic values on AC voltage applied to load was shown in Fig.10.

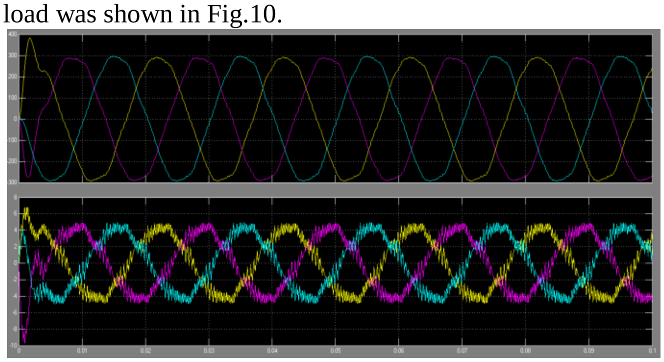

Fig.8. Inverter 3 phase output voltages and output currents.

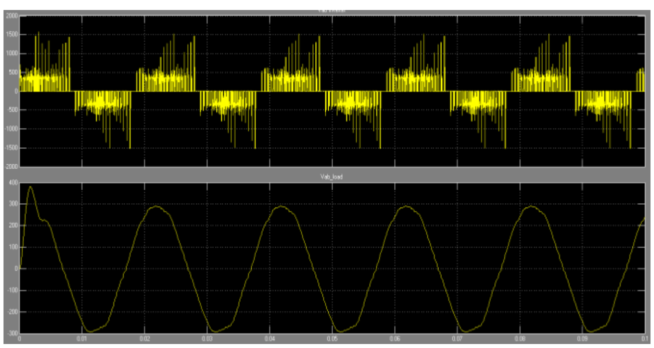

Fig.9. Inverter 1 phase output voltage and load voltage.

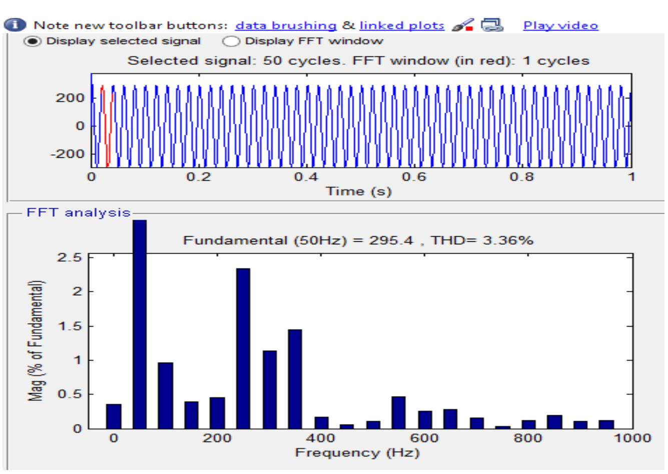

Fig.10. Load voltage harmonic analysis.

IV. CONCLUSION

A micro hybrid power system consisting of wind and solar panels is designed in this study. It is observed that the signals obtained from the wind turbine and the solar panel are distorted and contained high proportion of harmonics. These harmonics must be reduced to a minimum level before being transferred to the load as they will affect the system stability in a negative direction by reducing the efficiency of the system. For this purpose, it is aimed to form a complete sinus at the output end by using a 6-switched 3-level inverter due to its superior success in minimizing harmonics. Indirect control provides flexibility of controlling the voltage error; overcomes the previous algorithms which directly control the voltage error even though there is no such change to its value. As to verify performance of the proposed algorithm, evaluation under both steady state and dynamic operations has been carried out. Analysis in steady-state operation has widely been used before; thus, through additional analysis with dynamic operation which contributes to uniqueness of this work, more comprehensive results and findings have been obtained for further assessment. The proposed algorithm has successfully been demonstrated and comparative evaluation has been carried out with the established self-charging algorithms with PI or FLC in order to verify its better performance. The simulation work confirms that the proposed algorithm is able to achieve high accuracy in steady-state operation, and low overshoot with fast response time in dynamic operation.

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