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An Advanced Control and Stability Analysis of Wind Solar Integrated Microgrid

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***Abstract:** In this article, we suggest a micro-grid methodology based on renewable energy sources (RES) in order to make more efficient use of renewable energy sources and use less energy from the traditional power grid. Off-grid, RES likes solar (generated by a photovoltaic panel) and wind can be stored in a battery and utilised to power loads. As an additional measure, a Fuzzy logic-based energy-saving method has been applied. Microgrids are used to integrate these systems in a decentralised fashion, and they provide a suite of technology solutions that facilitate communication between end users and dispersed power plants. This raises the question of how best to administer these systems. In order to guarantee that both the generating and distribution systems produce energy at low operating costs, energy management in microgrids is described as a data and monitoring network that allows the required functions. In this study, we discuss the difficulties associated with using RES and managing a microgrid. Voltage and frequency variations result from the dynamic nature of DG systems. Unpredictable dynamics result from the load's unknowability. As a result of this nonlinear dynamic, there are observable changes to the microgrid's operation. In this study, we test the efficiency of the microgrid in a variety of settings. We compare the PI controller's performance on the MATLAB/Simulink platform to that of a Fuzzy logic-based controller with various levels of complexity.*

***Keywords:** Microgrid, RES, PI Controller, Fuzzy Logic, Wind System, PV System.*

1. INTRODUCTION

The expanding nature of the world's population is causing a corresponding rise in energy consumption. Energy production is rising in importance across the globe. There is a growing movement to solve the problem of energy production by turning to RES. Energy generated from renewable sources does not diminish the underlying resource. The most widely used forms of renewable energy include water, wind, sun, and bio-fuel/biomass. Typically, these fuels and energy sources are used for producing electricity, heating buildings, and powering vehicles. A key attraction of renewable energy is its inherent durability. As a consequence, we have a backup plan in case fossil fuels and nuclear power are depleted. The environmental effect of RES is far less than that of traditional energy sources. The rate at which we use power is rising far faster than the rate at which we can produce it. Therefore, a different strategy is required to meet the need. Since "Energy Performance - based assessment Is Equal to Electricity Generated," we've been thinking about various approaches of regulating energy use, which has led us to the notion of Load side Management. The term "capacity planning" refers to the practise of altering consumer demand using a variety of tools and strategies, such as Micro-grid operation techniques. For large microgrids, the analysis of dynamic and actuator factors with numerous DG units is simplified by the modelling and examination of power system methods using a range of DG units.

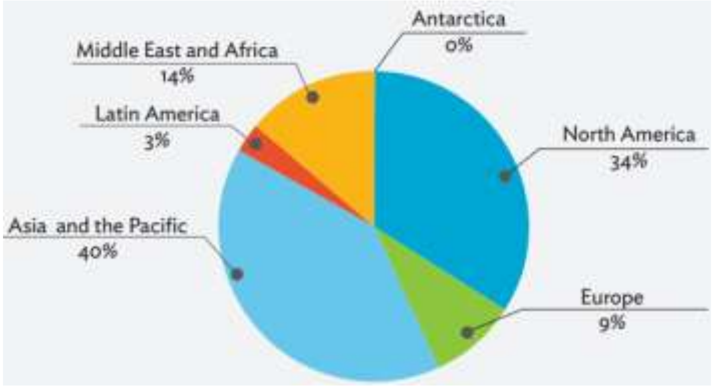

Fig.1: Capacity of microgrid in regions (scenario 2017).

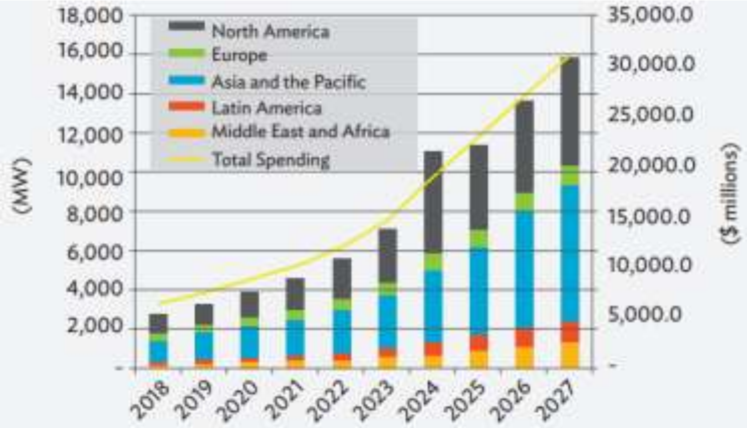

Fig.2: Microgrid capacity annual report (scenario 2018-2027).

Microgrids, in this narrower meaning, are defined as distributed, grid-connected energy systems of varied size that may be "islanded" at whim and are built primarily for local dependability, resilience, and maintenance economics. The term "islanding" refers to a situation in which DG continue to supply electricity to a certain area despite the lack of grid power. These microgrids that can function independently of the larger grid are the topic of this guide. Figure 1 shows that most of the world's microgrids are located in Asia and the Pacific, with the People's Republic of China providing the bulk of the region's capacity (PRC). There is no comprehensive database, but a half yearly tracker suggests that as of the fourth quarter of 2017, there were 1,869 microgrids with a combined capacity of 20.7 GW.

From 2018 to 2027, yearly capacity installations and spending on microgrids are projected to expand by about five times throughout the globe, with Asia and the Pacific and North America leading the charge (Figure 2). More money from public and commercial sectors, as well as a variety of financial instruments, will be needed for this.

For the developed framework, the DFIG additionally includes two voltage source converters (VSC). In contrast to the line side converter, DFIG also makes use of a rotor side converter that is attached to the rotor circuit (RSC). RSC is designed to maximise the efficiency of mechanical rotors in the wind by performing maximum power point tracking (W-MPPT). To increase the voltage of the solar PV array, it is linked to the DC bus through a solar converter. This setup allows for efficient evacuation of solar energy. To get the most out of the sun's rays, this converter also has a solar maximum power point tracking (S-MPPT) management approach. With the same RSC, the battery bank may be charged either from the grid or a diesel generator if the wind energy source is unavailable and the battery is at a low level of charge. Rated speed and energy at the input terminal are preserved with the aid of the LSC even when the following situations are present: Solar and wind power, in different quantities. Solar and wind electricity are not readily available. Disruption or loss of load in the supply system & also with Nonlinear and asymmetric loads are two examples.

Microgrid

The microgrid layout is shown in Figure 3. Distributed generation (DG), notably RES, point of common coupling (PCC), energy storage, and voltage source inverter are all parts of a microgrid. DGs are tiny, on-site or near-site energy generators. Examples of DGs include wind turbines, photovoltaic systems, biomass, hydroelectric energy sources, fuel cells, etc.

Fig.3: structure of microgrid.

These measures are meant to increase public trust in vital services, encourage the purchase of long-delayed assets, help meet emissions and renewable energy goals, and strengthen the bonds between neighbours. Its primary demographic consists of homeowners, and it is largely motivated by concerns of cost and safety (Figure 4). The use of these technologies by major corporations is hindered, however, by the need for further standards and the elimination of certain regulatory restrictions.

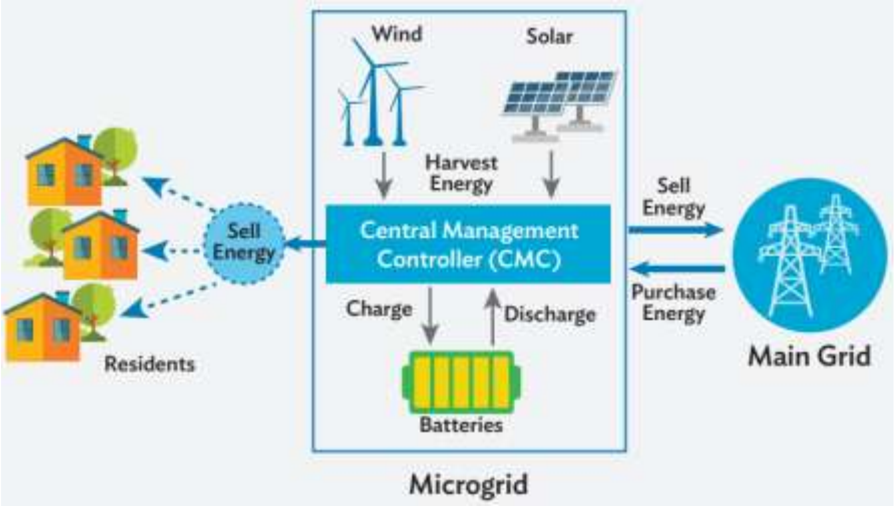

Fig.4: Overview of Typical utility microgrid.

System Modelling

In Fig. 5, we see a simplified schematic of the proposed REGS-fed micro-grid. The same has been planned for a site with a maximum power need of 15 kW and an average power requirement of 5 kW. Throughout REGS, both the wind energy block and the solar energy block are assumed to have a 15 kW rated capacity. Assuming a 20% capacity utilisation factor for both energy blocks, this meets the hamlet's daily energy needs. In the case of inadequate wind speed, the wind energy source is disconnected from the network using a three-pole breaker, as seen in the diagram. The battery bank serves as an interface between the DC sides of the RSC and LSC and the HV side of the solar converter. The WES relies on the RSC to keep it spinning at the correct speed, as determined by the W-MPPT algorithm. Network voltage and frequency are regulated by the LSC. Figure 6 shows an energy flow diagram for this system. Major REGS components, together with their respective design processes, are outlined below.

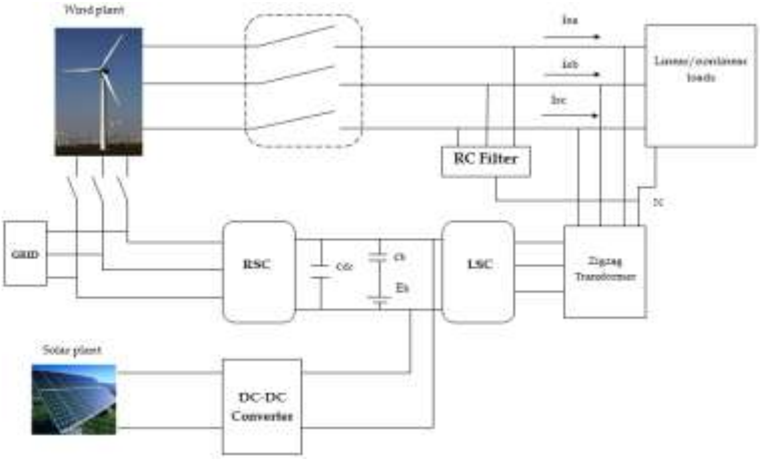

Fig.5: Proposed system configuration.

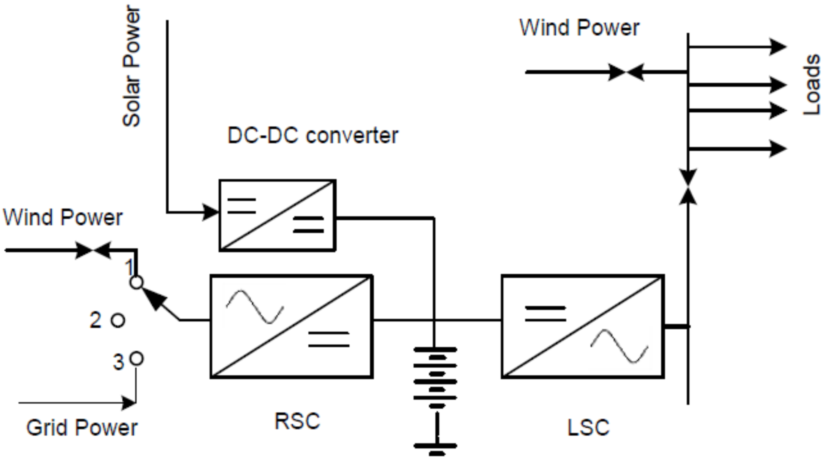

Fig.6: proposed system energy flow diagram.

The extent of reality is utilised in fuzzy logic, which is a computational method. The quantity of validity and linguistic components utilised by a fuzzy logic system are used to create a certain result. The kind of the output is decided by the state of this input.

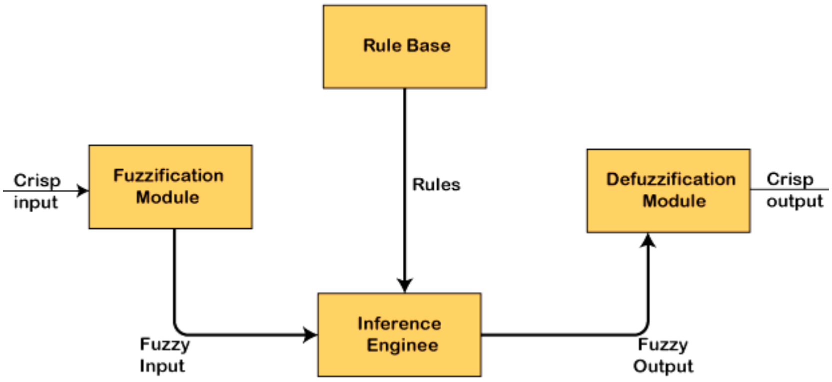

Fig.7: Fuzzy logic system.

In fuzzy logic, problems are defined and addressed by the application of rules that connect an expert's inputs with the intended results. An important influence on fuzzy logic comes from fuzzy sets, membership functions, linguistic variables, and fuzzy rules. A value of an input element is estimated or computed as a percentage of its membership in a fuzzy set, or other abstract set, using this function. As the x-axis represents the cosmos at large, the y-axis represents the various levels of involvement with that cosmos. The figure below is an example of a membership function.

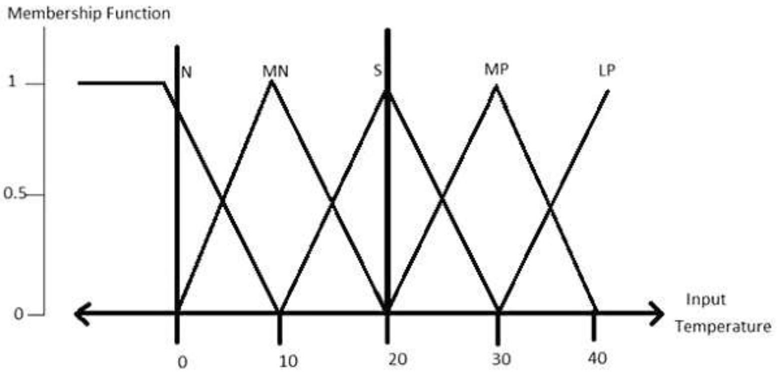

Fig.8: Membership rules.

Simulation Results

Case-1: wind condition

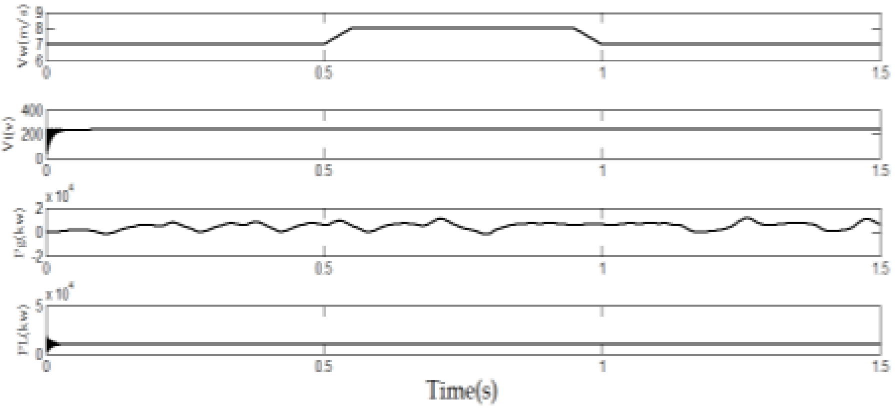

Fig.9: Existing system

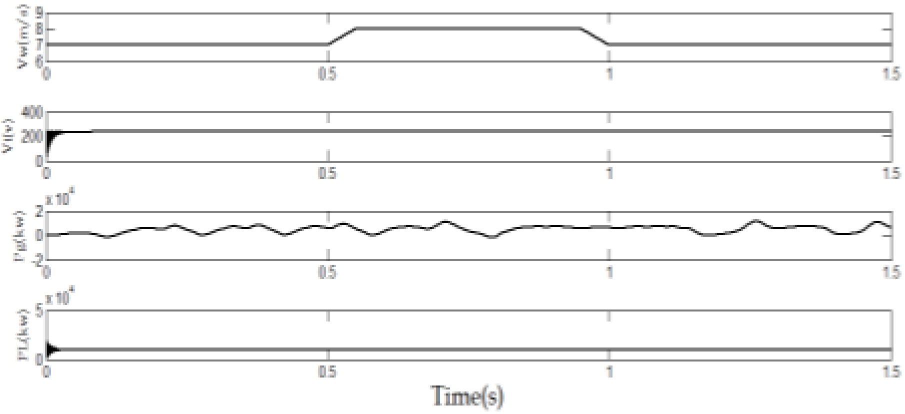

Fig.10: Proposed system

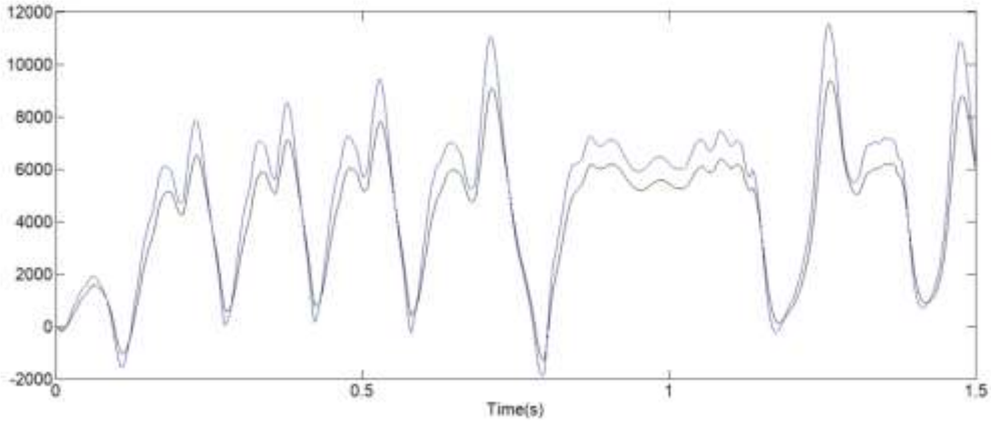

Fig.11: Comparison waveforms

In Figures, we start with a 10 kW and 6 kVAR demand but no renewable energy inputs. At t=0.05 s and a wind speed of 7 m/s, the wind generator is producing electricity. The voltage of the gadget will temporarily fluctuate as a result of this. The wind speed at the turbine increases from 7 m/s to 8 m/s at t=0.5 s, and then decreases to 6 m/s at t=1.0 s. The W-MPPT algorithm determines the best rotation speed, which is maintained by the rotor control operation. At t=1.4 s, the turbine is turned off.

Case-2: PV condition

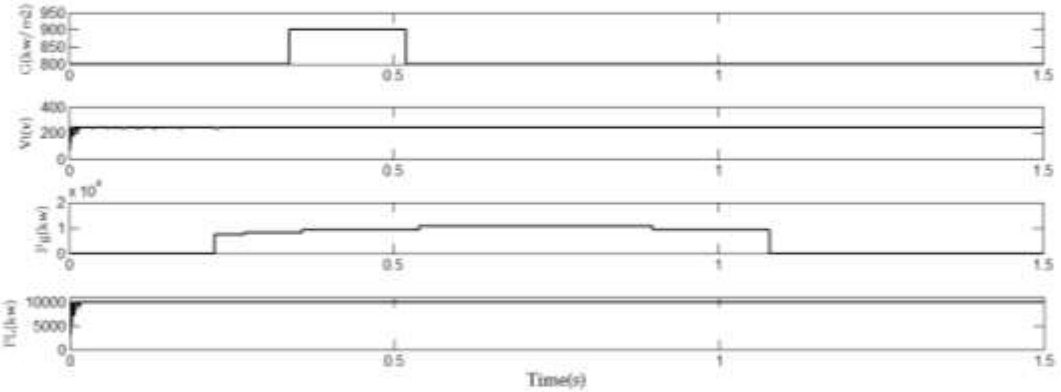

Fig.12: Existing system

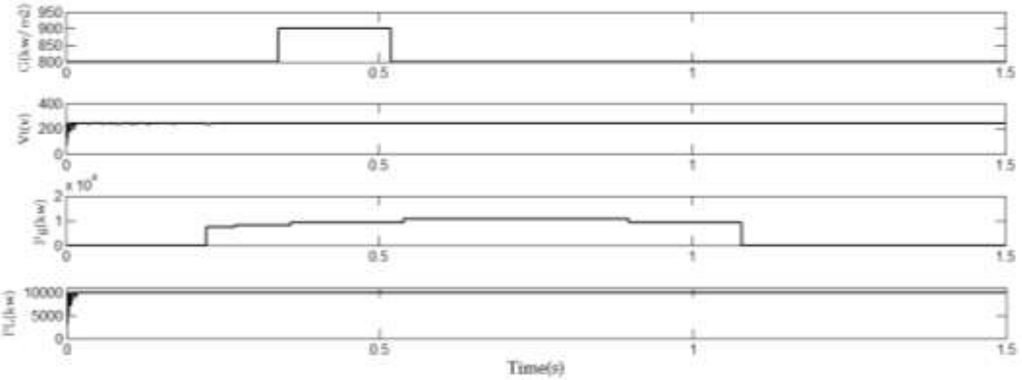

Fig.13: Proposed system

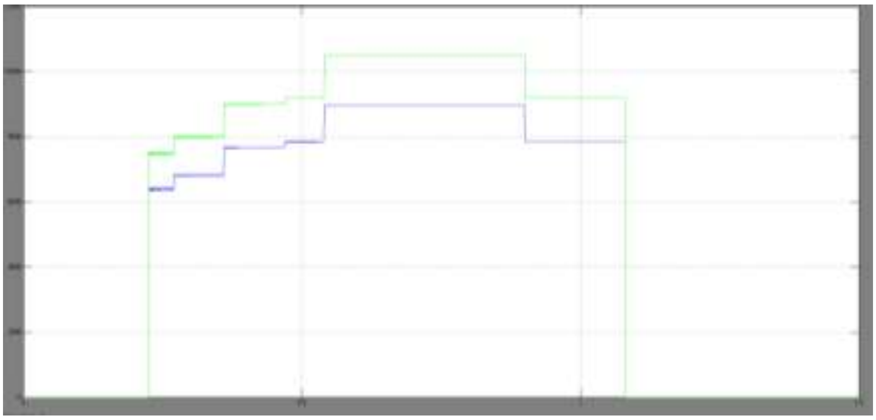

Fig.14: Comparison waveforms

For a 10 kW and 6 kVAR load, the device is deployed without the aid of wind or solar power. At t=0.05 s, the same solar system as depicted in Figures must be employed, which emits radiation at a rate of 800 W/m2. At t=0.34 s, solar radiation increases to 900 W/m2, and then drops to 800 W/m2 at t=0.52 s. When used in conjunction with S-MPPT, the solar converter regulates the voltage produced by solar photovoltaics. At t=1.08 s, the Sun and its satellites are taken out of commission. The voltage of the gadget does not vary noticeably at any of the transition points.

Case-3: Load changes

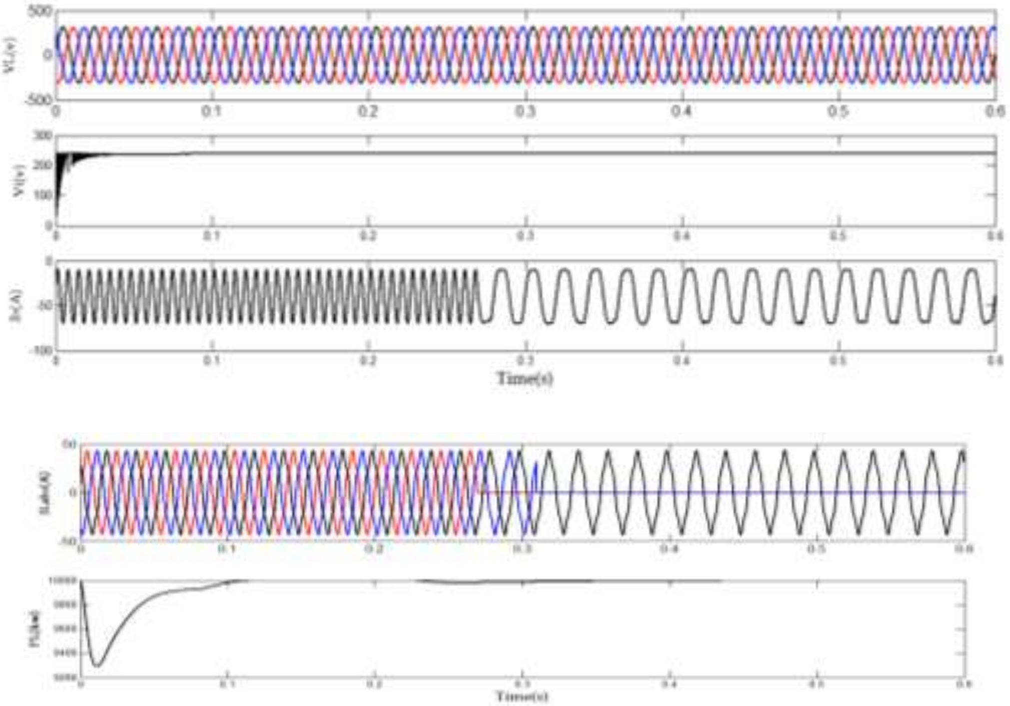

Fig.15: Exiting system

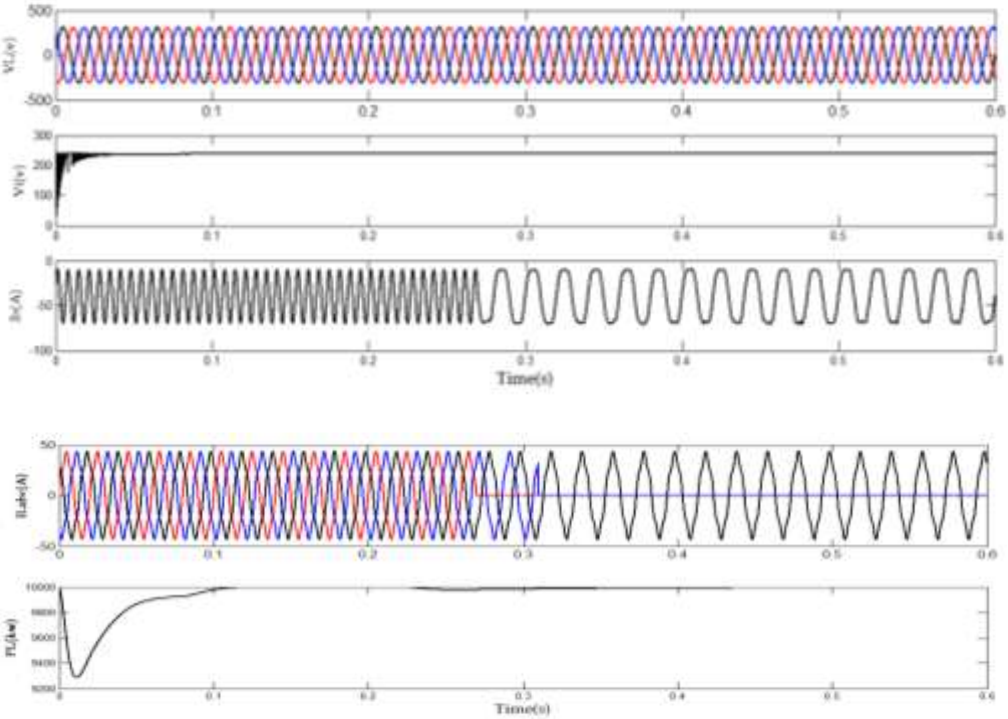

Fig.16: Proposed system

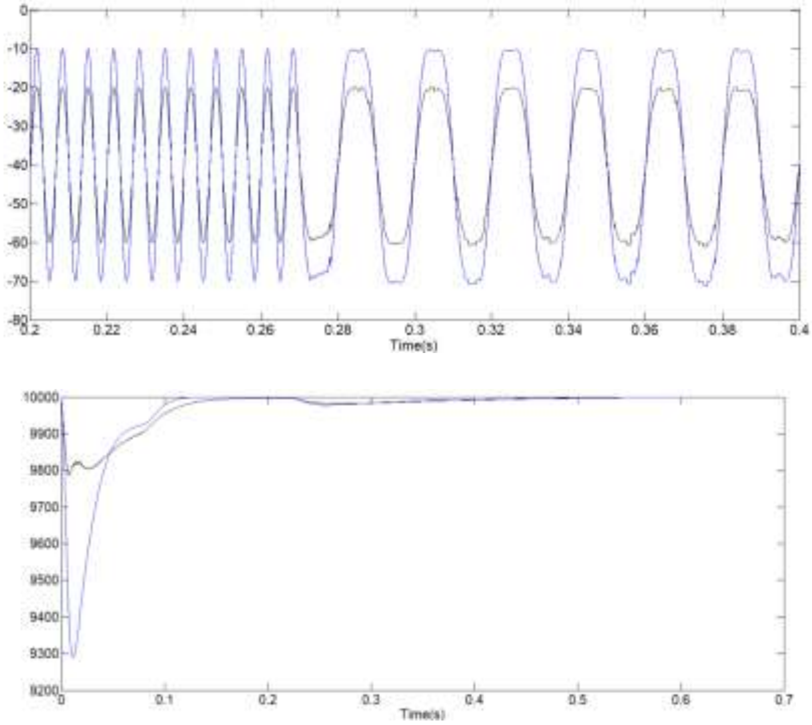

Fig.17: Comparison waveforms

The efficiency of an unbalanced nonlinear device is seen in Fig. 15 & 16. The micro-grid should be adequate to provide the nonlinear load that is not balanced. In the absence of any other options, we must assume the worst. Two kilowatts (kW) of linear energy and eight kilowatts (kW) of non-linear power are linked with the load. The a-phase load is disconnected from the network at time t=3.25 s, followed by the b-phase load at t=3.46 s. The outcomes demonstrate that even under nonlinear and unequal loads, the device still delivers reliable power.

2. CONCLUSION

The load requirements of a small number of homes in a distant area have been determined to be met by the planned REGS micro grid system. REGS incorporates wind and solar energy blocks that are meant to harvest optimal energy from RESs and provide consumer grade electricity in parallel. The gadget is meant to be completely operational. Major component sizes are also included in this study. The system's output was shown to account for variations in input circumstances for various load profile types. The power quality at the load terminals never deviates outside of a tolerable range. The accuracy of the procedure was demonstrated using MATLAB/SIMULINK.

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