

**Fuzzy Logic Controller based Dynamic Stability Enhancement of WPGS, PV and Super capacitor inter-connected system**S.SRIKANTH¹, P.AMRUTHA²¹ P.G Student, S.K.U College of Engg. & Tech., S.K. University, Ananthapuramu-515 003.² Lecturer in EEE Department, S.K.U College of Engg. & Tech., S.K. University, Ananthapuramu-515 003.

Abstract: This paper proposes a new method for enhancing the dynamic stability enhancement of a hybrid wave and photovoltaic(PV) power generation system integrated into a distribution power grid. The wave power generation system (WPGS) is simulated by a linear permanent magnet generator (LPMG) driven by an Archimedes wave swing (AWS). The output of the WPGS and the PV system are connected to a common DC-link through a voltage-source converter(VSC) and a DC/DC boost converter, respectively. The common DC-link is interfaced to the distribution power grid via a voltage-source inverter (VSI). A super-capacitor (SC) is utilized to smooth the generated power delivered to the distribution power grid. The proposed control scheme to maintain stable operation of the system while achieving maximum power extraction for the wave system and the PV system is test in matlab environment and results are compared with conventional controller.

Keywords: wave power generation system (WPGS), linear permanent magnet generator (LPMG), Archimedes wave swing (AWS), Super-Capacitor (SC).

I. INTRODUCTION

Energy from renewable sources is being considered as a viable alternative to fossil fuels. Thus large-scale renewable energy power-generation systems are united into the mass power transmission networks [1],[2], the increasing usage of the small-scale renewable energy sources (RESs) in the distributed generation systems is further the current trend. To improve the system reliability, economical, and/or system efficiency, etc., two or more RESs can be merged together or with the conventional non-renewable energy sources such as FF forming the hybrid power-generation systems (HPGSs) [1],[3],[4].

Owing to fluctuating and intermittent nature of the RESs, such as battery, super-capacitor (SC), superconducting magnetic energy storage (SMES), hydrogen etc., are usually required in the HPGSs for power back-up to regulate and/or smooth the fluctuated power. Such HPGSs can handle in standalone mode to supply the isolated loads or in grid-connected mode [4]. Response to the rapid development of batteries, battery energy storage systems lately have undertaken to be utilized for various applications such as frequency regulation, grid stabilization, transmission loss minimizing, reduce congestion, amplify reliability, wave and solar energy smoothing, spinning reserve, peak-shaving, load-levelling, uninterruptible power sources, grid services, electric vehicle(EV) charging stations and others[5].

In increment, they can be consumed locally, consequently reducing both impacts from high-voltage transmission lines through rural and scenery and power losses [6]. In a context where the security of fission-based nuclear power is cross-examined and FFs may represent a consequential hazard due to their intimation in climate swap, it seems clear that there exists a certain need of developing clean and sustainable power source alternative [7].

However, ocean energy which is generous RES has been steadily developing towards pre-commercial and commercial operation in coming years. Thus the ocean energy allures more and more attention. With the profile of low investment and high energy density, the ocean wave energy seems to be one of the abundant energies that can be converted to electrical power, enabling devices to extract more power from a smaller volume at consequent lower costs and reduce visual impact[8]-[10]. The Archimedes Wave Swing (AWS) is a unique wave energy conversion system as it is completely submerged. This is significant, because this makes the system less endangered in storms. Anyhow it is invisible, so that the public approval is not an issue as for, for example, wind frame[11].

While a tremendous research on the topics of wave power generation systems (WPGSs) has been handled and declared, the combination of WPGSs with other RESs in HPGSs has not been widely studied. A standalone PV-wave hybrid renewable power generation system for performing in island area of Malaysia. In that hybrid scheme, the WPGSs was stimulated by a permanent magnetic synchronous generator (PMSG) driven by an oscillating water column device and the battery bank was used as a backup energy-storage system.

In this, the dynamic stability enhancement results of a grid-connected wave and PV HPGS with the help of the SC for smoothing out the power fluctuations are propounded. A commanded plan is initiated to sailing power fed to the grid and maintain the stable operation of the studied system while extracting maximum power from both PV and wave

renewable resources. The presentation of the studied system and the effectiveness of the SC integrated with the proposed commanded scheme are inspected through fuzzy logic research results of the system.

II. MODELING OF SYSTEM COMPONENTS

PV ARRAY & DC-DC BOOST CONVERTER:

The PV array is collection of many PV modules interconnected in series and/or parallel. Each PV module is comprised by a number of PV cells connected in series fig.1 shows the single-diode equivalent-circuit model of a PV cell [14], [15].

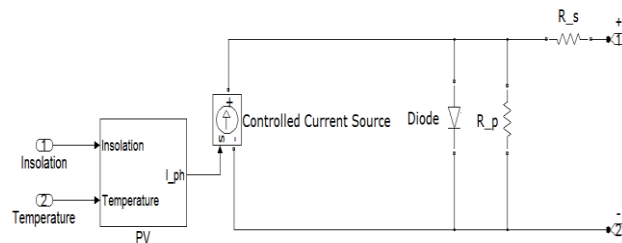


Fig.1 Single diode model of PV system.

The boost converter is a step-up DC-DC switching converter. With the help of boost converter, the low input-voltage level can be boosted up to a useful high output voltage level, essentially functioning like a reversed buck converter. The boost converter topology is shown in fig.2

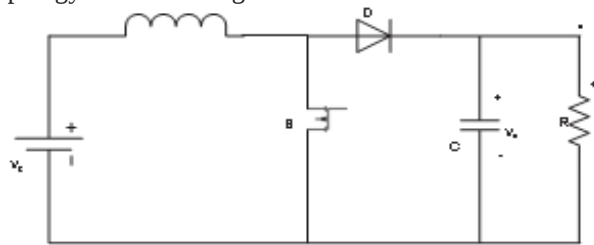


Fig.2 DC-DC boost converter.

AWS & WEC SYSTEM:

In the past, different types of wave energy conversion(WEC) devices have been developed [8]-[10]. Among the WEC devices developed, Archimedes wave swing(AWS) is the first WEC device to adopt the direct-drive power takeoff technique, which leads to higher energy conversion efficiency. Employing LPMG, the wave energy can be converted to electrical energy. Since the translator of LPMG reciprocates, the direction and speed of the motion of the translator vary. Subsequently, the frequency and magnitude of the induced voltage and stator current as well as the output power vary [9]-[12]. These characteristics of the LPMG cannot satisfy the grid code for the integration of the wave generation into the power network. Hence, the power conditioner should be designed to integrate the AWS based WEC into the power grids.

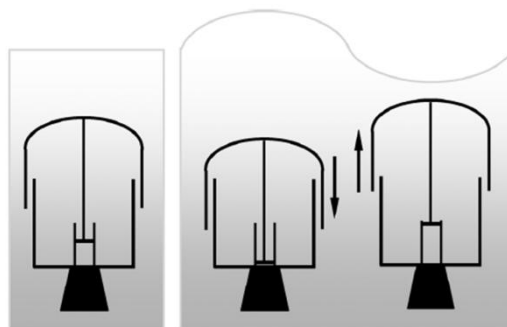


Fig.3 Configuration of the AWS

The mass-spring-damper system [17] can be used to model the dynamics of the AWS. Thus, the mechanical dynamics of the AWS can be described by the motion equation as follows [6], [8].

SUPER CAPACITOR:

Super-capacitors, also called electrochemical capacitors or ultra capacitors, are widely used in several industrial domains as a promising high power energy storage device [18].

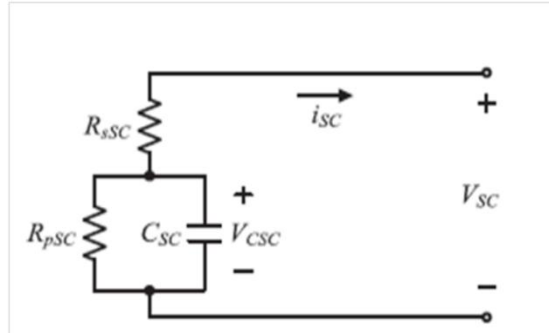


Fig.4 Configuration of the Super capacitor.

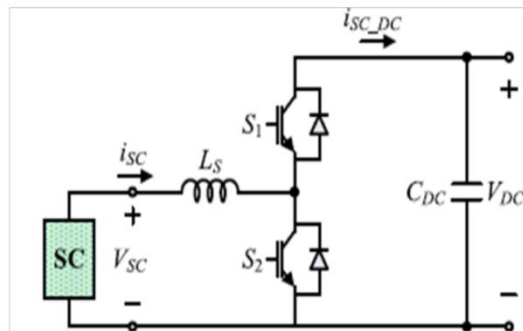


Fig.5 Schematic diagram and dynamic average-value model of the bidirectional dc/dc converter.

III. DESIGN OF CONTROLLERS

In this paper two controllers are used one is conventional controller (PI Controller) and second is proposed Fuzzy Logic Controller (FLC). The PI controllers for various components are shown in figures 6 to 7.

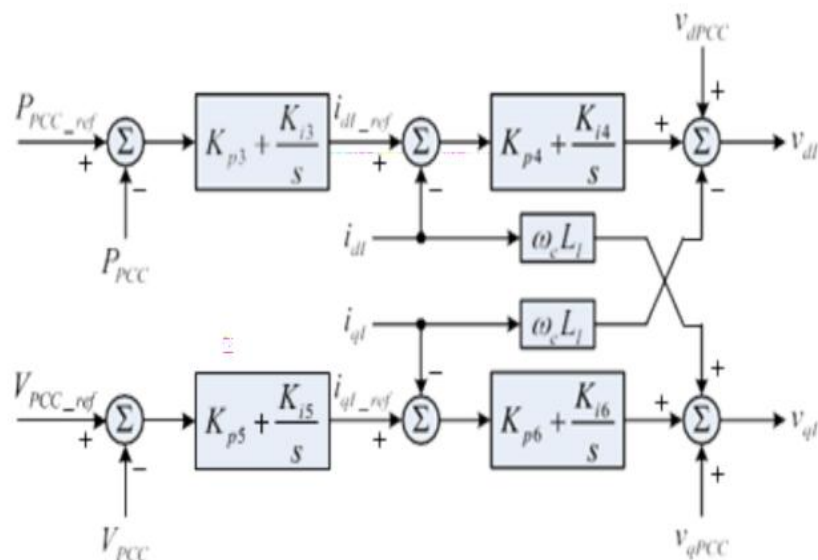


Fig.6 Control block diagram of the VSI.

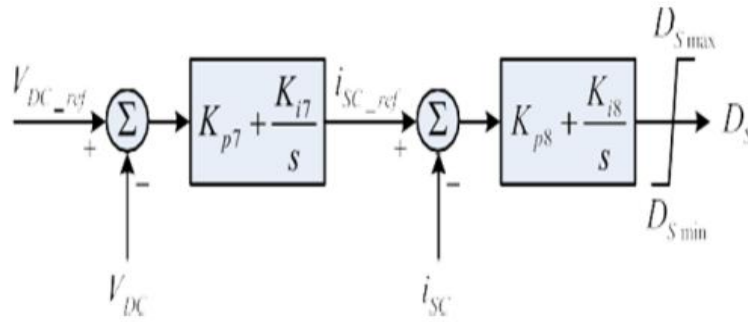


Fig.7 Control block diagram of the bidirectional dc/dc converter.

Figures 8 to 11 shows fuzzy membership functions and rules.

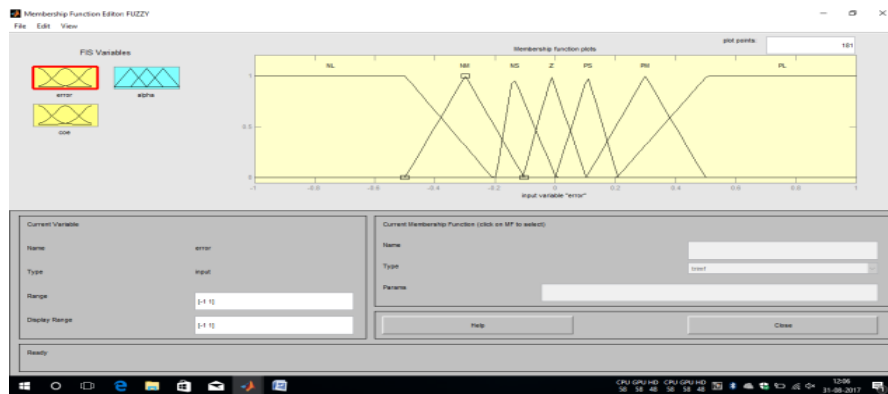


Fig.8 Input 1 membership functions.

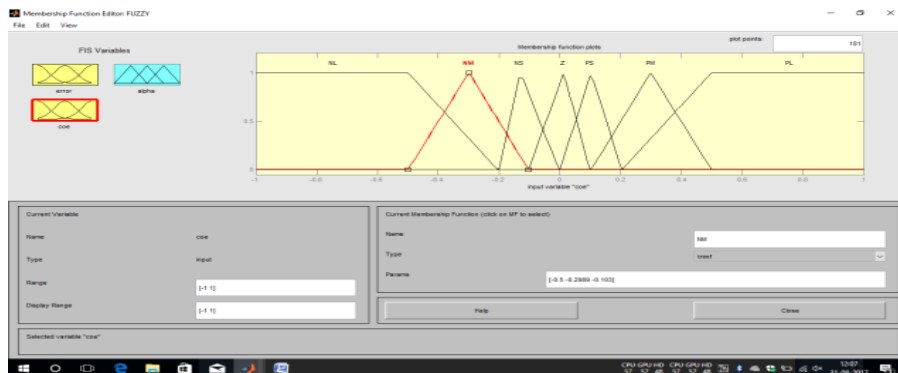


Fig.9 Input 2 membership functions.

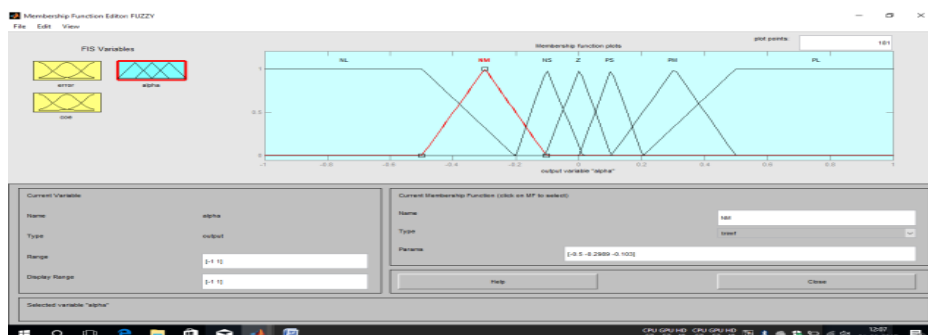


Fig.10 Output membership functions.

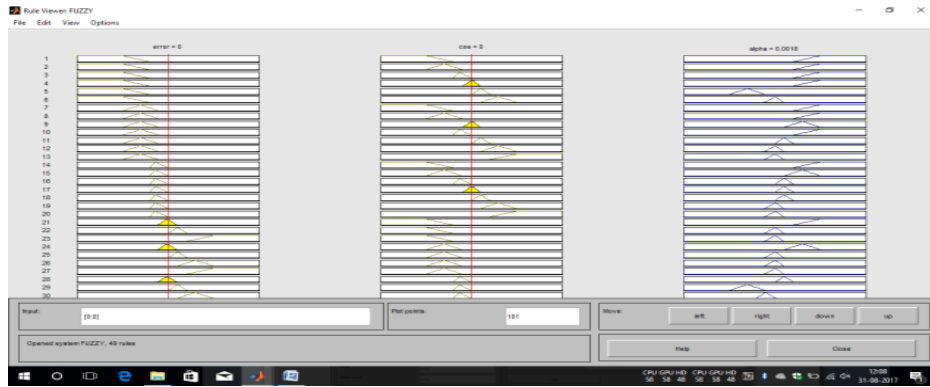


Fig.11 Fuzzy rules.

IV. TEST SYSTEM & RESULTS

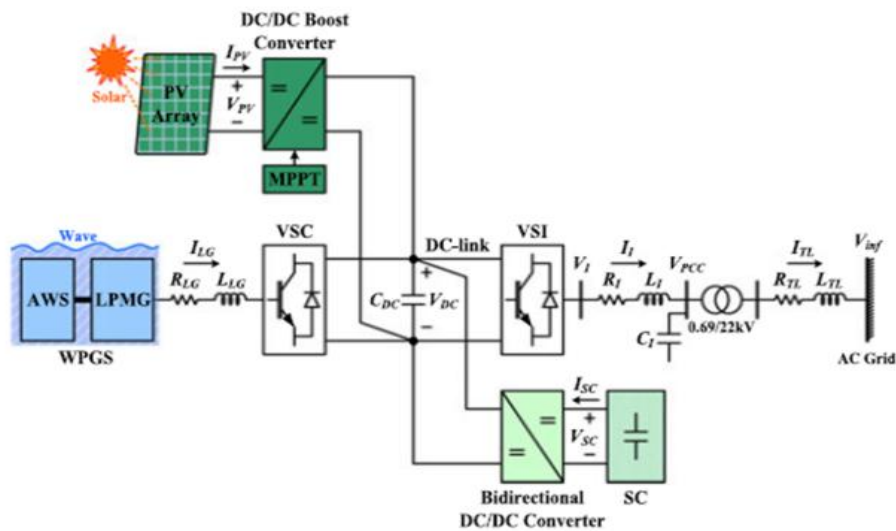


Fig.12 Configuration of the studied hybrid wave and PV system integrated to grid.

Case 1: Dynamic responses of the studied system under the variations of the wave force acting on the AWS of the WPGS.

In this part, the wave force acting on the AWS of the WPGS is subject to the variations as depicted in Fig.13 while the solar irradiance is assumed to be constant at 200 W/m². Initially, the peak amplitude and the period of the wave force are 0.7MN and 12 s, respectively.

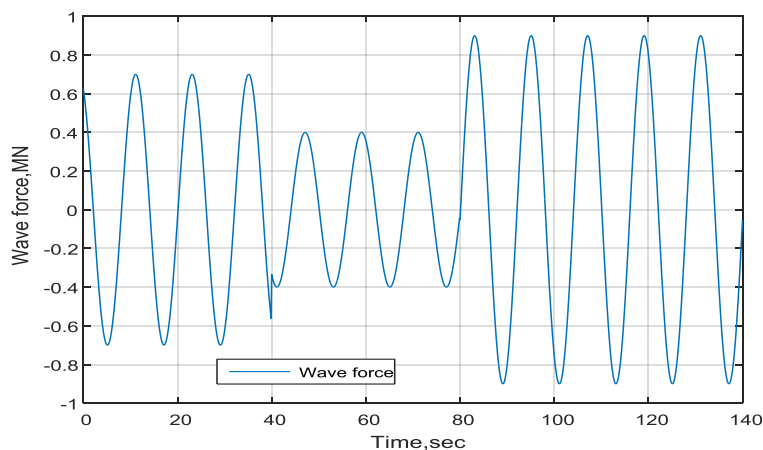


Fig.13 Wave force.

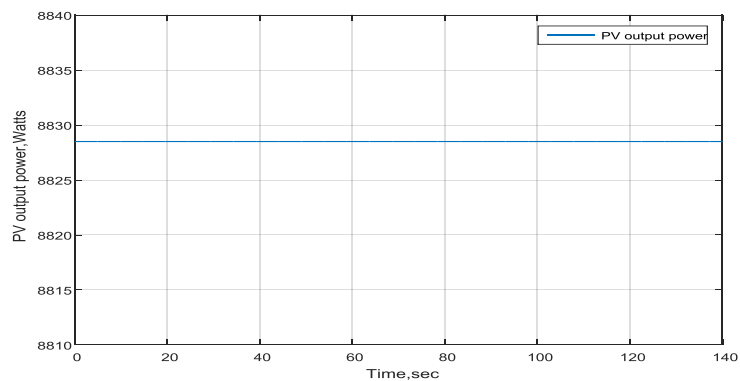


Fig.14 PV source output.

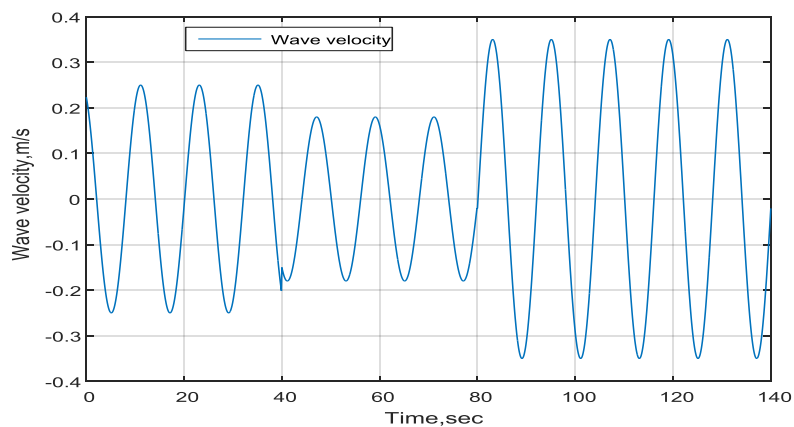


Fig.15 PV Wave velocity.

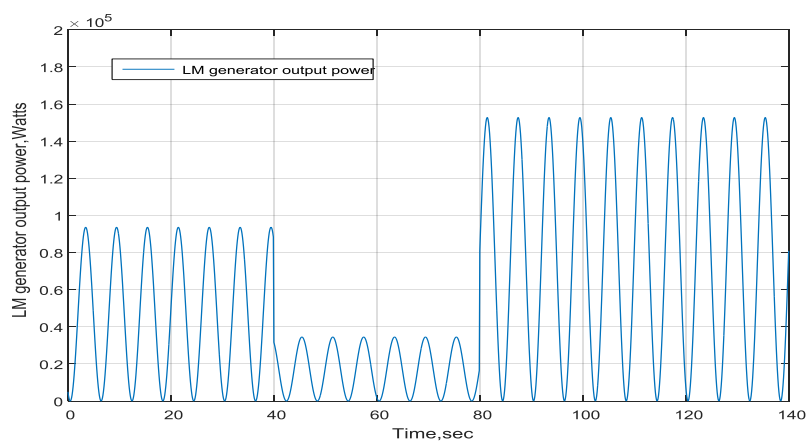


Fig.16 WPGS output.

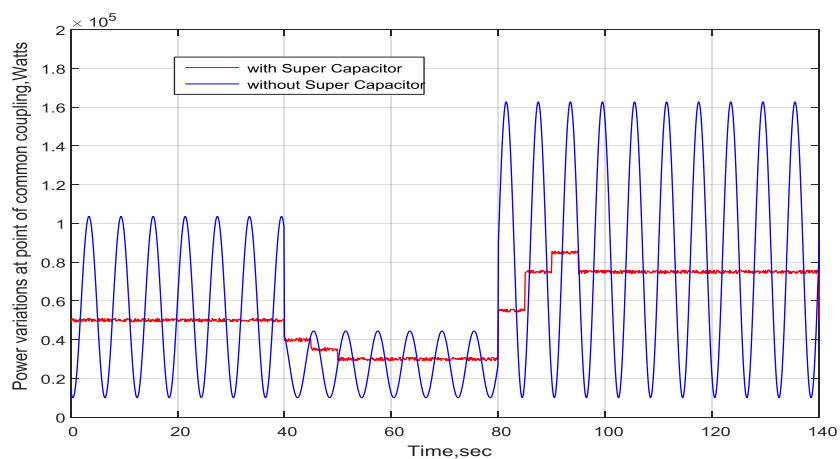


Fig.17 power variations at PCC.

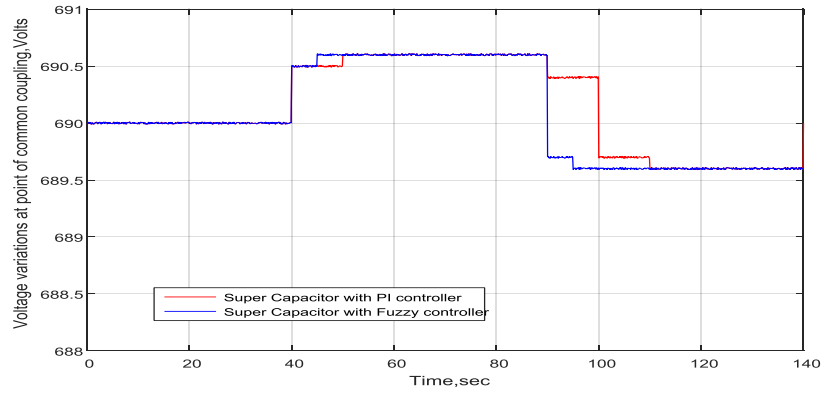


Fig.18 voltage variations at PCC.

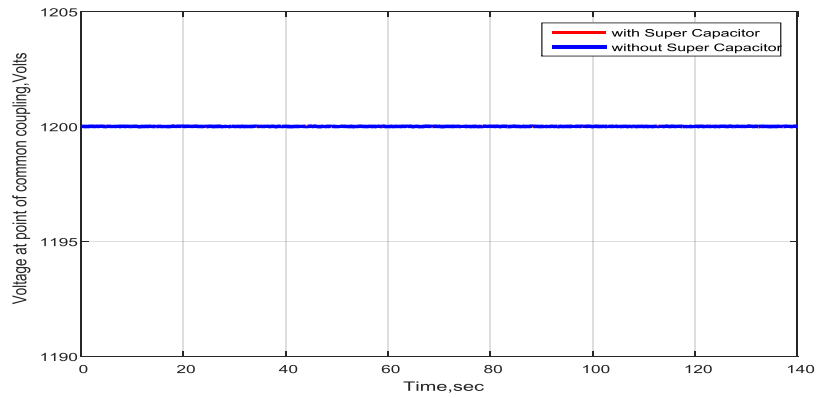


Fig.19 voltage at PCC with and without Super capacitor.

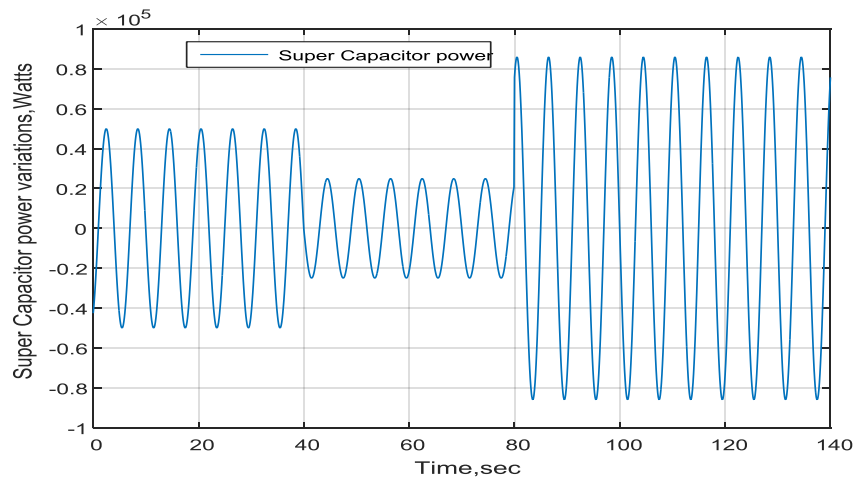


Fig.20 super capacitor power variations.

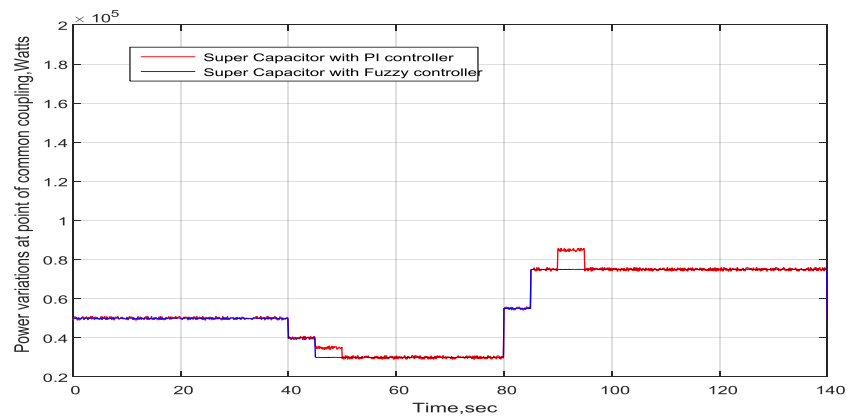


Fig.21 Power variations at PCC with PI and Fuzzy Logic controller

Case 2: Dynamic responses of the studied system under the variations of the solar irradiance.

In this part, the solar irradiance at the PV array is subject to the variations as shown in Fig.22 whereas wave force is kept at the peak amplitude of 0.2 MN and the period of 12s. The solar irradiance is assumed to be increased from the initial value of 200W/m² to the maximum level of 1000 W/m² at $t = 50$ s and gradually reduce back to 200 W/m² at $t = 200$ s.

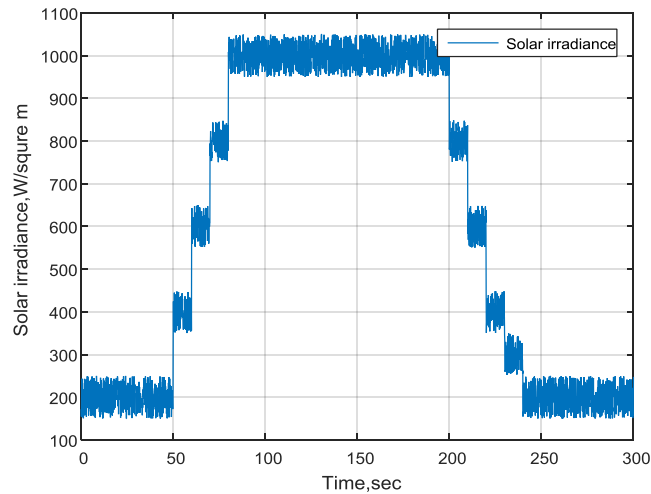


Fig.22 Solar irradiance.

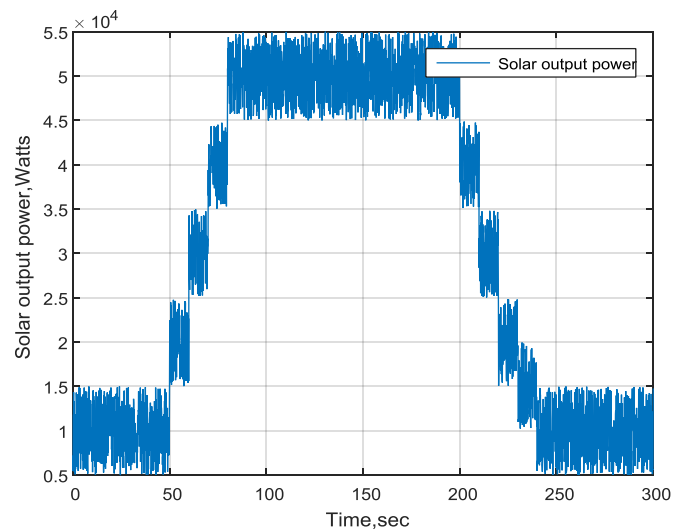


Fig.23 Solar Output.

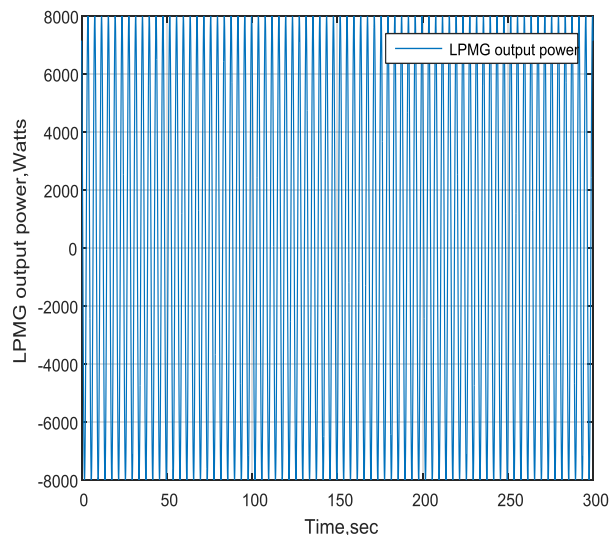


Fig.24 WPGS output.

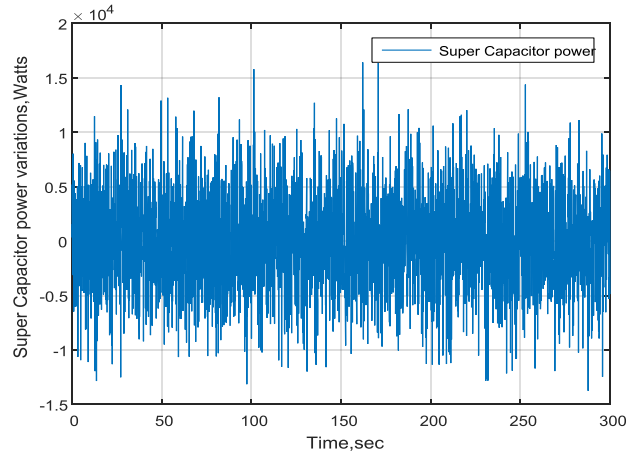


Fig.25 super capacitor power variations.

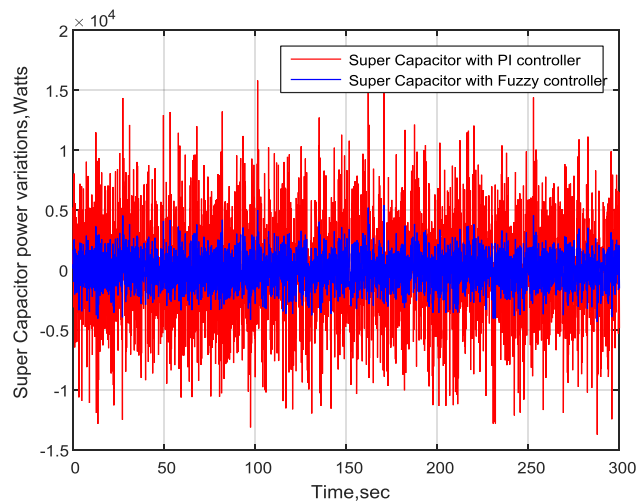


Fig.26 Super capacitor power variations with PI and Fuzzy controller.

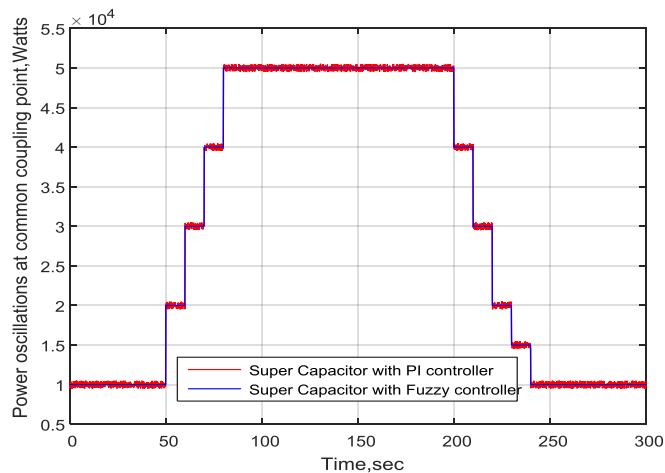


Fig.27 Super capacitor power variations with PI and Fuzzy controller.

From the results it is concluded that the Fuzzy logic controller damping the power oscillations in both the cases effectively as compared with PI controller. The fuzzy logic controller reduces the magnitude of power oscillations and also setting time is reduced by 15seconds as compared with PI controller.

V. CONCLUSION

In this paper, the dynamic stability analysis results of a hybrid wave and PV system integrated into a distribution power grid have been presented. An SC-based energy-storage system has been employed to support for smoothing out the power fluctuations. A control scheme has been proposed aiming to suppress the power fluctuations from feeding to the distribution power grid and maintain stable operation of the studied system while achieving the maximum power

extractions from the PV array and the wave power-generation system. Both modal analysis and time-domain simulations of the studied system have been performed to examine the dynamic performance of the studied system under various operating conditions. It can be concluded from the simulation results that the proposed control scheme the ability to maintain stable operation of the studied system under various operating conditions while extracting the maximum power from both the renewable-energy sources. It can also be concluded from the simulation results that the SC combined with the proposed control scheme can effectively smooth out the power fluctuations of the studied hybrid wave and PV system

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