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CONFERENCE PAPER

INTELLIGENT TYPE 2 FUZZY LOGIC CONTROLLER FOR SOLAR BASED HOME ENERGY MANAGEMENT SYSTEM

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Abstract

In order to lessen the strain on individual energy storage systems in renewable energy sources, energy storage systems have recently seen an increase in hybridisation. An effective power-sharing plan is required as energy storage becomes more hybrid. In order to efficiently use hybrid energy storages in the solar-powered energy system, this paper suggests a power sharing technique based on interval type 2 fuzzy logic controllers. The hybrid energy storage system used in this study is primarily powered by solar energy and includes a battery and supercapacitor. The supercapacitor supports fast-varying power, while the battery supports slow-varying power. The solar panel's maximum power is tracked using the perturb and observe technique. The MATLAB/Simulink platform is used to design the suggested system.

Introduction:-

Recently, severe climate change, including global warming and poor air quality, has put all life on Earth in jeopardy and sparked global concerns about massive petrol emissions and energy-related problems. Integrating energy storage systems is essential for operations like grid stability, and dependable power supplies. Several energy management strategies have been established in the literature to preserve the energy balance and, consequently, simply enhance the power quality while taking cost into account [1]. Systems that store energy in batteries have been chosen and used in numerous applications. Recently, hybrid energy storage systems (HESS) have gained significant impact due to their efficiency and robustness in the energy sector. By combining several types of energy storage devices, HESS seeks to maximise energy storage system (ESS) efficiency [2-4]. Ideal ESSs are characterised by their great energy and power density. It is impossible to achieve this behaviour with a single energy storage device. The SC is unable to maintain power for an extended length of time, but it can quickly discharge a significant quantity of power. In contrast, the battery reacts slowly to a step change in load. However, it has the capacity to maintain the same level of energy for a long time. When the battery and SC work together, the ESS response is optimal and power may be produced quickly and sustainably. Furthermore, a power-sharing approach is essential to the efficient use of HESS.
Power management, voltage, and frequency regulation in freestanding

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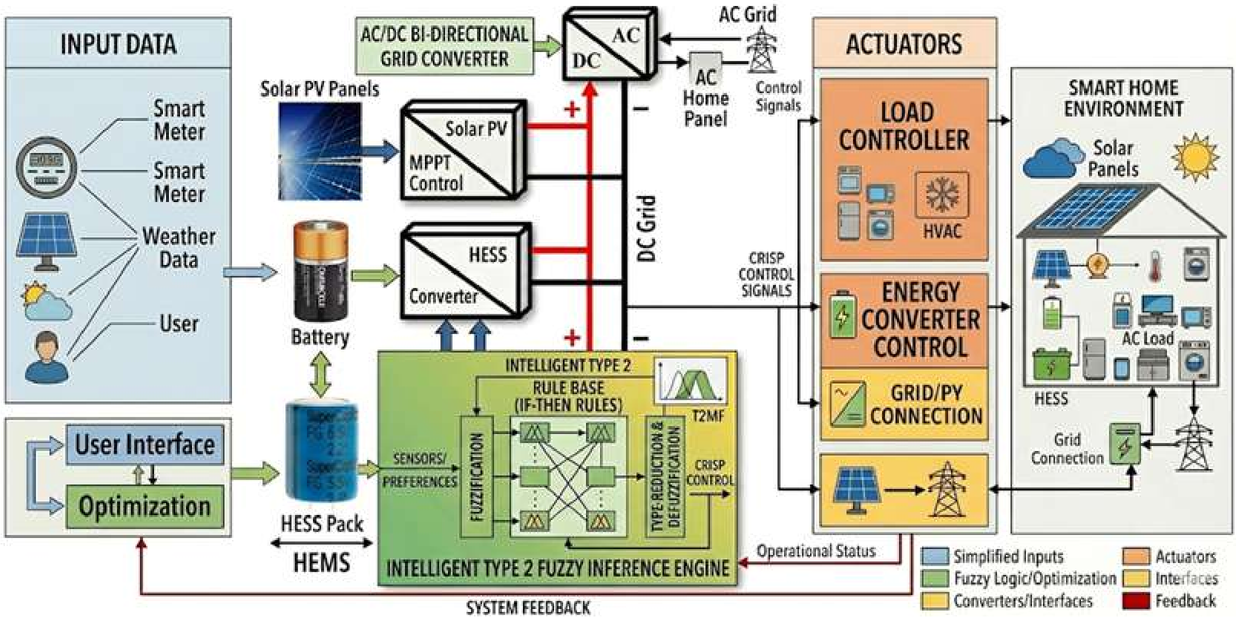
DC microgrids fuelled by photovoltaic, battery, and hydropower are covered in [5-7]. Battery-ultracapacitor HESS in plug-in EVs is managed by a reinforcement learning-based system in [4]. For battery-SC HESS, a nonlinear model predictive control-based energy management approach is used in [8]. In [9], a new power management method for battery and SC HESS-powered EVs is used. In [10-12], the energy management system for battery-SC HESS in solar applications that is based on heuristics is examined.

In contrast, a type 2 fuzzy logic control (T2FLC) approach has been used for a number of applications because of its ability to manage uncertainty effectively. In [13-16], a T2 Mamdani FLC is researched for a variety of industrial applications, such as maritime diesel engine speed control, liquid level control, steel strip mill temperature control, mobile robot control, etc. After that, an T2FLC is used to improve the low voltage ride-through capabilities of wind turbines that are powered by permanent magnet synchronous generators [17,18]. In order to evaluate voltage sag in the distribution system, the T2FLC was examined in [19]. The implementation of T2FLC for a shunt converter linked charging scheme follows in all of the aforementioned programs perform better when using an T2FLC.



Type-2 Fuzzy Logic Controller

Since there are currently a lot of efforts in this field, type-1 fuzzy systems are not discussed here. The usage of membership functions, where the membership is fuzzy rather than crisp, is the primary distinction between Type-2 fuzzy systems and Type-1 systems. Although this isn't always the case, Type-1 makes the assumption that membership can be allocated as a precise numerical number. On the other hand, the idea of the footprint of uncertainty is proposed to model uncertainty in real-world issues since it is believed that there is uncertainty in knowing the values of the membership in general or interval Type-2 fuzzy sets.

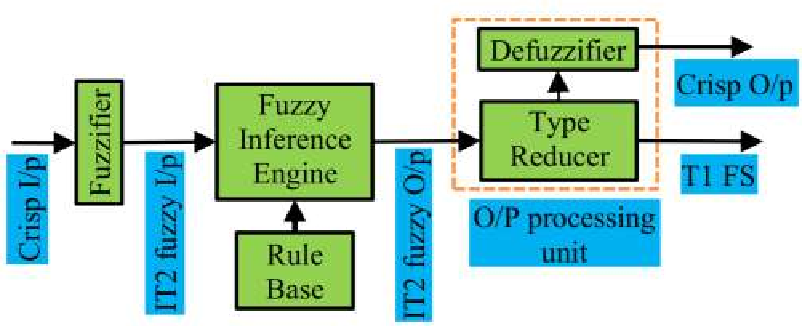


Fig 1: Internal Architecture of Type-2 Fuzzy Logic System

Proposed Type-2 Fuzzy Logic Control Strategy

Three bus power system models are represented by four state variables. State variable behaviour with regard to time is possible through the use of integrator blocks, which integrate the derivative of the state variable. Different controllers receive inputs that differ between the reference voltage and the actual voltage. Since sensitive nonlinear dynamical systems have numerous states of equilibrium close to unstable chaotic points of operation, the controller's output is utilized to disrupt the system to emerge from bifurcation or chaos. The controller's variable reactive power setting will alter the reactive power loading to new modified values of reactive power. As a result, the controller keeps an eye on voltage deviations from the reference value. Analysis was done on three scenarios.

1. A PID controller-equipped system.
2. A system using a fuzzy logic controller of Type-1.
3. A system using a fuzzy logic controller of Type 2.

In the presence of several controllers, the power system's state equations are solved using the MATLAB-Simulink software platform. In MATLAB, the Simulink platform is used to simulate each state equation. It also includes integrator blocks and functional blocks of PID, fuzzy logic type-1 controller, and interval type-2 fuzzy logic controller. To obtain state variables, the first order derivative of each state variable is integrated. When state variables are combined linearly, the derivative of the state variable itself is produced.

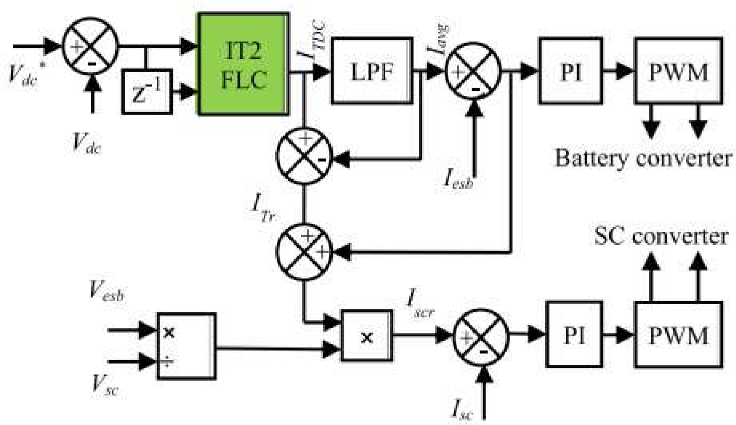


Fig 2: MATLAB/Simulink model of the proposed control system using Type-2 Fuzzy Logic Circuit

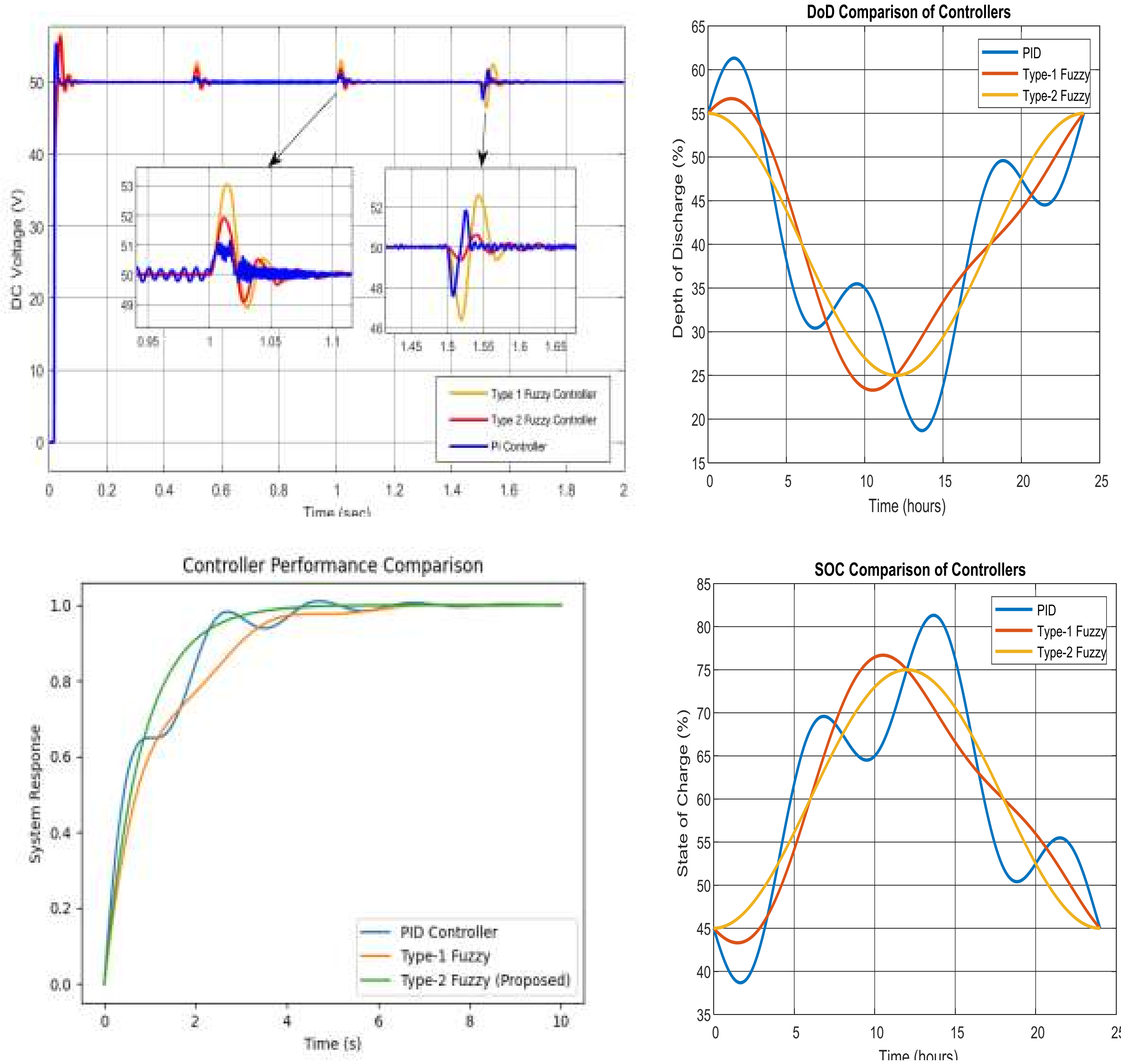
Results and Discussion:-

Without a controller, the voltage output varies erratically, which causes instability. The nature of the state equation, particular parameter values, and particular initial conditions are to blame for this. When a PID controller is used to adjust the reactive power, there is less voltage fluctuation and no instability. The voltage fluctuations are further reduced by the Type-1 fuzzy logic controller design, and no indication of instability is seen. The Type-2 FLC design produces a voltage profile that is almost flat, with minimal voltage variations and no instability.The SOC and DoD comparison clearly demonstrate that the Type-2 fuzzy controller maintains a smoother charge-discharge profile with minimal fluctuations, thereby reducing battery stress and improving lifespan compared to PID and Type-1 fuzzy controllers.

Table 1: Comparison of performance parameters of the 3 systems under study

Parameter	PID Controller	Type-1 Fuzzy	Type-2 Fuzzy (Proposed)
Rise Time (sec)	1.8	1.2	**0.8**
Settling Time (sec)	5.5	3.2	**2.0**
Overshoot (%)	18%	8%	**1–2%**
Steady-State Error	0.05	0.02	**0.005**
Peak Time (sec)	2.5	1.8	**1.2**
Control Effort	High	Medium	**Optimized**
Noise Sensitivity	High	Medium	**Low**

Fig 3: Comparison of Voltage, SOC, DOD performances of the system using PID, Type-1 FLC and Type-2 FLC



Conclusion:-

Instability may result from system complexity manifested as chaos at any time, which causes significant energy disturbance. It is concerning when parameter values are uncertain and lead to such chaos-driven instability. A type-2 fuzzy logic controller is essential for managing chaos in an environment with erratic parameters and beginning conditions. Fuzzy logic controllers of type-2 can be used to effectively control the system's uncertainties and dynamics. In order to comprehend the extent of instability impacting a broad customer base, the electricity system was selected as a suitable instance in the paper, and the application of type-2 fuzzy logic controller was suggested. An example of a big nonlinear dynamic system is the power system. It is easy to conclude that systems with interval type-2 fuzzy controllers are the best option to prevent chaos-driven instabilities after closely examining the obtained results in the form of time domain waveform, phase plane trajectory, and integral square error. This is because these controllers prevent instability and produce a flat voltage profile in uncertain error conditions of the system. A better response than a type-1 fuzzy logic controller requires careful rule design and framing. The paper's comparative performance supports the usage of intelligent and more practical type-2 fuzzy logic controller.

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