Autonomous Coordination of Multiple PV/Battery Using ANFIS controller Hybrid Units in Islanded Microgrids

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Abstract: In this paper, a manipulate method is developed to achieve fully autonomous energy control of multiple pv/battery using ANFIS controller hybrid units in islanded microgrids. Additionally, the evolved method has the capacity to autonomously coordinate with dispatch able droop controlled gadgets. The energy furnished by way of the hybrid units is autonomously determined primarily based on the available electricity from all hybrid units, the overall generation capacity of the to be had dispatch able gadgets, the overall load call for, and the SOC of all batteries in the microgrid. Further to retaining the energy balance within the microgrid, the decentralized coordination scheme prioritizes charging the micro grid batteries with lower SOC. Also, the manage method enables the hybrid gadgets to import power from different devices to support charging their batteries. Those capabilities are executed by means of employing the proposed multi-segment adaptive power/frequency (P/f) traits in the hybrid unit controllers. Since the approach is primarily based completely on the local voltage controllers, neither a important EMS nor communications amongst special gadgets are required.

Keywords—Micro grid, droop control, PV, battery storage

I .INTRODUETION

Photovoltaic (PV) arrays in each standalone generation devices, and in islanded micro grids require battery garage to characteristic successfully. This is due to the intermittent nature of the PV strength manufacturing, which relies upon on the solar irradiance and ambient temperature. In both configurations, battery storage is needed to keep the generation/intake stability in the system, at the same time as permitting the law of the weight voltage [1]–[4], however in islanded micro grids, keeping strength stability is greater complicated within the presence of PV resources, due to numerous factors. First ,micro grids are maximum likely to have a couple of PV/battery gadgets, which require coordination to hold the strength balance, while cooperatively regulating the microgrid voltage/frequency in the normal running variety. 2nd, PV gadgets are normally controlled as present day resources to deliver all of the available PV strength to the microgrid (the PQ manage strategy [5]. This control approach is inherited from grid connected schemes, wherein keeping energy stability among load and eraisn't an difficulty, on the grounds that it's far ensured thru the grid. 0.33, micro grids generally incorporate dispatch able devices to make certain the continuity of the supply. Inside the literature, these gadgets normally use hunch control techniques to coordinate the voltage and frequency regulation while sharing the active/reactive power [5]–[9]. Therefore, PV and battery systems need to also be capable ofH. Mahmood, and J. Jiang are with the department of electrical and computer Engineering, In any other case, they should either stay idleor be charged while surplus strength becomes available. In other phrases, the battery most effective materials electricity while all different devices reach their limits, to keep away from depleting the battery upfront. Additionally, charging/discharging have to be coordinated with other gadgets primarily based at the battery kingdom-of-price (SOC), the burden, and the available PV electricity. Consequently, islanded micro grids with PV generation require complete coordination to operate effectively and reliably. The most trustworthy technique to this coordination problem inside the literature, is to appoint centralized manage techniques that require communications between gadgets and primary power management gadget (EMS). More especially, a conversation failure at any unit can also jeopardize the microgrid operation, as that unit becomes invisible to the EMS. To keep away from reliance on communications and central manipulate techniques, autonomous or so known as decentralized energy management for islanded micro grids has recently obtained a outstanding deal of interest within the literature The techniques evolved in are centered on the outside power drift among the PV/battery unit and the micro grid. Consequently, devoted controllers of the DC-DC converters and the PV curtailment are not taken into consideration. Discrete control modes, applied the use of a state-device, are utilized in, which ends up in sizable transients And chattering while switching between some modes. Hybrid PV/battery systems provide extra flexibility from the electricity control point of view because the local manage gadget has access to the battery SOC estimate, in addition to the PV energy measurements.

This paper offers a control strategy for PV/battery hybrid gadgets to attain fully decentralized power management in islanded micro grids. The developed strategy gives comprehensive electricity management that overcomes the limited.

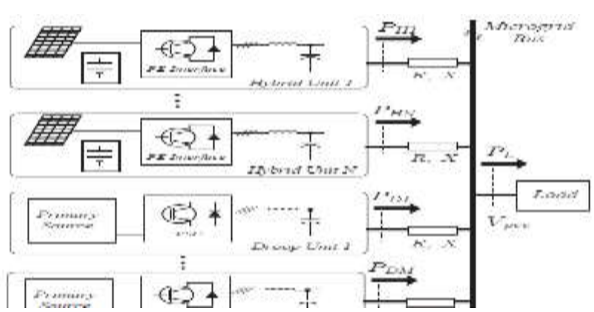


Fig. 1. Structure of the considered islanded microgrid.

Applicability, and transient drawbacks, of the above noted existing techniques. It is able to autonomously manage a couple of PV/battery structures, and has the ability to coordinate with dispatch able hunch controlled devices (if any are available) in the microgrid. This is done through adopting the proposed adaptive multi-segment P=f characteristics. These proposed multi-section traits, along with their multi-loop manipulate implementation, bring about smooth transitions most of the manipulate targets. The manage strategy is carried out locally at each hybrid unit. The complete control tasks are done with outage liance on direct communications among those units. The developed control strategy and operating scenarios are mentioned in section II. Simulation effects that validate this approach are offered in segment III, observed via concluding remarks.

II. PROPOSED CONTROL STRATEGY

A simplified diagram of the microgrid structure taken into consideration in this paper is proven in Fig. 1; in which N and M represent the wide variety of PV/battery hybrid units and stoop controlled gadgets, respectively. The considered PV/battery hybrid device is proven in Fig. 2, together with the proposed control system. The battery bidirectional DC-DC converter is controlled to adjust the DC-link voltage, while the PV DC-DC converters controlled to inject the PV strength into the DC-link. Subsequently, the PV converter is controlled to adjust the PV array terminal voltage to extract the available PV energy. The manage system of the voltage sourced converter (VSC) is operated as a voltage supply that follows the proposed multi-phase P=f characteristic curve, that's commonly dependent as shown in Fig. 3. This parent is provided hereto reveal the fundamental shape of the multi-phase P=f characteristics. The parameters of these function curves can change adaptively primarily based at the device working situations.

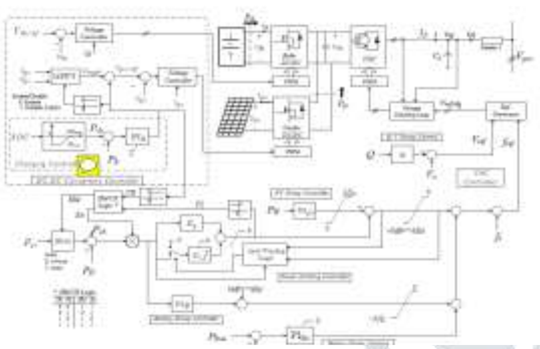


Fig. 2. Architecture of the proposed control system.

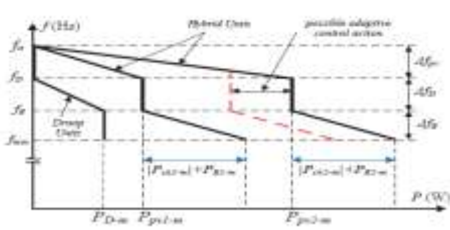


Fig. 3. General structure of the proposed multi-segment P=f characteristics

This may be illustrated in element, later in this segment, the usage of numerous operating situations. The P=f stoop characteristics of all hunch controlled units are aggregated into one curve in Fig. 3, which represents an equivalent slump unit with a complete power potential of PD-m = PD1 + PDM. The foremost consciousness in this paper is at the actual power management as in, even as reactive electricity sharing can be carried out the use of the traditional reactive power/voltage hunch control method. Reactive strength control in islanded microgrids has been reviewed in the proposed P=f characteristics for all devices are divided into three segments in the frequency variety of [f o; fmin], where info and fmin define the running frequency limits of the microgrid. These frequency segments are the PV section (f pv), the droop section (f D), and the Battery phase (f b), which might be defined over the frequency levels of [f o; f D],[f D; f B], and [f B; fmin], respectively. Notice that, the proposed=f characteristics are based in order that the principle objective of the hybrid unit is to charge the battery every time possible, and to discharge it only when all gadgets reach their generation limits, or at some stage in low PV manufacturing and top load intervals. Different programs, which include marketplace anticipation and economic dispatch, can also require communications among gadgets and centralized algorithms that operate above the number one manage layer, and are taken into consideration beyond the scope of this paper. The adaptive change in the P=f characteristics, and the transition of the P=f operating point alongside these characteristics, is decided by way of the proposed manipulate loops based totally on three variables: PH, P ch, and P pv, wherein PH is the strength supplied by using the hybrid unit to the micro grid, P ch is the charging strength reference, and Ppv is the power produced via the PV array, and may be measured at the DC-link at any time. Word that, Ppv is identical to the maximum available strength handiest whilst the PV array operates on the maximum strength point (MPP). The auxiliary common sense desk proven in Fig. 2 is best used to preserve one of the manipulate loops idle underneath certain conditions, as may be explained within the following subsections. The reference Pch is generated by using the Charging Controller shown in Fig. 2, as a feature of the battery SOC.

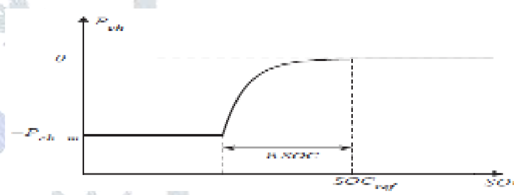


Fig. 4. Battery charging curve

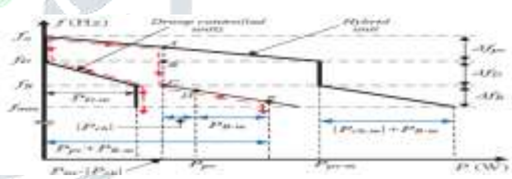


Fig. 5. P=f trajectory in response to an increase in the load demand. Operating conditions: Ppv Ppv-m, and jPchj> 0.

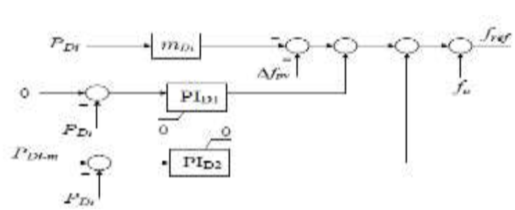
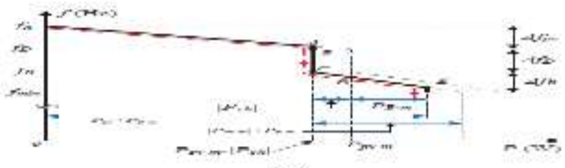
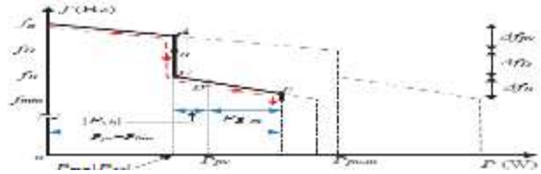


Fig. 6. Droop control system with a shifted operating frequency range

A. Basic Operation

The multi-segment P=f characteristic curve is shown in Fig. 5 for a hybrid unit at arbitrarily chosen operating conditions of Ppv < Ppv-m, and j Pchj> 0, where Ppv-m refers to the PV power rating for this unit. In the PV Segment, the hybrid unit operates as a voltage source to meet the load demand together with other hybrid units based on the frequency droop control defined in this region. The slope of the droop curve is defined in this segment as mpv = fpv=Ppv-m. The battery converter regulates the DC-link voltage by directing the surplus power (Ppv..PH) to charge the battery. PV curtailments typically performed in this segment. At this stage, the value of Ppv is held constant, and the Power Limiting Controllers disabled using the logic signals Hld = 1 and En = 0, respectively (see Fig. 2). The curtailment scenario will be discussed in detail in the next subsection. The frequency continues to drop with any increase in the supplied load demand, while following the P=f trajectory indicated by the red dashed line, until PH = Ppv..JPchjatpoint A in Fig. 5. At this point, the unit starts tracking thePV maximum power point (MPP), which results in the logic signals Hld = 1 and En = 1 (see Fig. 2). In response to any further increase in the load, the Power Limiting Controller starts regulating the unit output power at PH = Ppv .. jPchj by reducing the frequency. This results in PL = 1, and accordingly Hld = 0. In other words, the hybrid unit starts to operate as a power controlled source, to assign a higher priority to charging the battery. Note that the Power Limiting Controller operates only when the unit is tracking the PV MPP, as will be discussed in more detail in the next subsection .Meanwhile, the other hybrid units either continue to share the increased load or limit their output powers depending on the Ppv and Pch values at these units. At point B, the summation of the total load demand in the microgrid and the total charging power from all units' equals the total PV power available from all units in the microgrid. At this point, the P=f trajectory enters the Droop Segment. Ifno droop units were deployed in the microgrid, the frequency continues to drop in this segment until it reaches point C. Thesis due to the power limiting action of the hybrid units. If there are droop controlled units in the micro grid, they will start supplying any increase in the load between points B and C, as illustrated in the P=f trajectory shown in Fig. 5. The microgrid frequency is regulated by the droop units, which are acting as master units in this segment. The hybrid units follow the change in frequency to limit their output powers at the set limits. These limits are not fixed though, and are determined by the available PV power and the battery SOC, as will be discussed later in this section. Note that droop control systems are traditionally designed to limit the output power between zero and the maximum power using two PI control loops. The only slight difference in this case is to set the frequency operating range between fD and fB, as shown in Fig. 5, instead of the typical range of[fo; fmin]. This droop control system is presented in Fig. 6, where mDi, PDi, and PDi-m are the droop slope, output power, and power rating of Droop Unit i, respectively. The droop units continue to supply the increased load until they reach their maximum output power limits, at the same time when the hybrid unit reaches point C. The droop units will respond to any further increase in the load by limiting their output powers at their maximum limits. The Power Limiting Controller in the hybrid unit is designed to start limiting output power only when PH tends to increase beyond Ppv .. Pch. This may occur at any frequency in the range of [fo; fD], depending on Ppv, Pch, and PH. Therefore, the Power Limiting Controller requires an anti-windup control with variable saturating limits. This is implemented using the developed anti-windup arrangement shown in Fig. 2. the designated operation range of the Power Limiting Controller is limited between an upper limit that can





(b)

(c)

Fig. 7. P/f characteristic segments for different levels of PV generation and a fixed charging reference

Begin anywhere within the range of [fo; fD], and a lower restriction off. This operation variety is represented by using the P=f phase AC in Fig. 5. The top restrict may be visually known as the P=f point in which the trajectory leaves or meets the PV hunch line, e.G. Factor A in Fig. 5. In other phrases, in any

scenario, as soon as the operating factor reaches the PV stoop line, or the frequency restrict fb, the output of the strength restricting Controller will saturate and therefore stop limiting the output power. The placement and duration of segment AC, that represents the running variety strength limiting Controller, is adjusted adaptively based at the to be had PV strength and the charging reference (PH = Ppv jPchj); and for this reason the location and period of the opposite segments vary as a consequence. This is illustrated in Fig. 7, using the P=f function segments for extraordinary levels of PV era and a hard and fast charging reference of Pch. Word that the P=f segments are adjusted at each unit independently. Including extra devices in the microgrid, will handiest trade the weight share contributed by every unit in keeping with its own P=f characteristics. The strength limiting Controller limits the output strength at Ppv=jPchj best till the P=f working point reaches point Cat f = fb. Past this factor, the hybrid unit starts operating inside the Battery phase as a slump unit once more, the use of the battery slump controller shown in Fig. 2. In other words, the output strength of the hybrid unit may be decided by way of the weight call for. In response to the growing output power PH, the battery DC-DC converter reduces the charging strength to maintain the DC link voltage regulated at Vdc-ref. This process continues with any similarly boom within the load until the charging electricity is decreased to 0 at point D. At this point, the hybrid unit materials all of the to be had PV strength to the micro grid. The increase in the load might be furnished thereafter from the battery until the battery maximum energy is reached at factor E. At this point, the Battery strength limiting Controllers begins running to restrict the output power. Further growth in load can be supplied with the aid of the batteries of other gadget still all the batteries inside the micro grid have reached their most strength limits. At this level, the frequency is reduced by using the Battery strength restricting Controllers under fmin. This usually triggers a load shedding ordinary, that's beyond the scope of this paper.

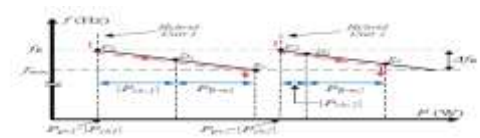


Fig. 8. Supplying peak load from two hybrid units with different SOC

Be aware that the units with higher SOC, i.E. With less jPchj, start discharging earlier than those with decrease SOC. That is illustrated in Fig. Eight for two same hybrid units however with specific SOC degrees. In this example, Unit 2 with the better SOC starts discharging first at point D2. The battery hunch manage slopemBi for the Hybrid Unit i is decided as

$$m_{Bi}=\frac{\Delta f_B}{P_{ch-mi+}P_{B-mi}} \qquad (1)$$

Where Pch-mi, and PB-mi are the maximum charging strength, and the battery converter maximum electricity rating for the Hybrid Unit i, respectively. Word that mB defines the slope of the P=fbattery droop section; but, the duration of this section inany unit is determined based totally at the battery charging reference Pch in that unit. The period of this P=f segment will increase from CD in Fig. 9a to CDE in Fig. 9b, whilst jPchj will increase from zero W to Pch-m = PB-m.All of the manipulate actions mentioned so far had been in reaction to modifications in the load demand. Those major control objectives and movements are summarized inside the Appendix. The trajectory of the P=f running factors in response to growing electricity era is proven in Fig. 10. On this parent, Hybrid Unit 3 is working at its rated PV strength with a completely charged battery, whilst batteries within the other devices are still being charged. To simplify the discussion, the focus might be on Hybrid Unit 2. First of all, the running point of Hybrid Unit 2 is at A. At this point, the hybrid unit operates within the stoop section to modify PH at Ppvo = jPchj. IfPpv begins growing at Hybrid Unit 2, the power restricting

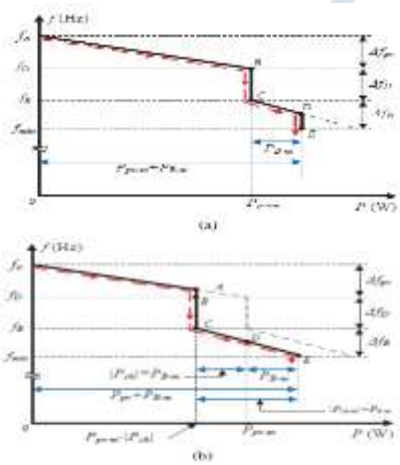


Fig. 9. P/f characteristics for different levels of charging power, and Ppv = Ppv-m. (a) jPchj = PB-m. (b) jPchj = 0W..

Controller begins increasing its output electricity PH to comply with the new growing limit of (Ppv□jPchj). As explained formerly, that is equal to transferring the P=f segment AC in Fig. 7further to the right. This shift within the P=f traits emphasized in Fig. 3, the usage of the blue colored traces, whilst the PV manufacturing at Hybrid Unit 2 increases from Ppvo to Ppvo + Ppv1, and then Ppvo + Ppv1 + Ppv2. The devices in the micro grid reply to this growth in the output strength of Hybrid Unit 2 as follows: The output energy of the stoop units decreases, at the same time as the the frequency increases consistent with their droop characteristics. Accordingly, all of the hybrid gadgets observe this transformation within the frequency to keep regulating PH at their limits. Hybrid Unit 2 follows the growth in the frequency at the same time as growing its output power. This consequences within the P=ftrajectory AB. Word that the slope of this section is identical to that of the equal hunch unit. This because of the fact that the hunch gadgets are accountable of regulating the frequency in this region. Each Hybrid Unit 1 and Hybrid Unit three preserve regulating their output powers at their limits, at the same time as following the increase in frequency. At factor B, the overall output strength of the droop gadgets reduces to 0, and all the load is supplied via the hybrid units. More particularly, at this point Hybrid Unit 2 picks up all of the load percentage of the droop gadgets. In other phrases,Ppv1 = PD.A similar P=f trajectory can bring about reaction to a decreased battery charging reference Pch, because the SOC will increase. If there's a in addition growth (lower) in Ppv (Pch), the micro grid will start running within the PV section, which autonomously triggers the PV curtailment mechanism, as may be discussed next.

B. PV Curtailment scenario

1) VSC manipulate movements: At point B in Fig. 10, the overall strength available inside the micro grid matches the overall of the micro grid load and the charging power. If Hybrid Unit 2 PV energy increases past Ppvo + Ppv1, the hybrid units start running in the PV section. Which means that the summation of the load and the charging electricity within the micro grid is much less than the to be had PV strength generation. As soon as the machine reaches point B, the electricity limiting Controller in Hybrid Unit3 reaches its running range limit, as defined previously. Consequently, in Hybrid Unit 3, handiest the PV hunch controller is energetic at this factor. The gadgets in the micro grid reply to any similarly boom within the PV electricity at Hybrid Unit 2 as follows: stoop units: keep their output powers at 0.Hybrid Unit 1: maintains regulating its output strength at itsPpv = jPchj restriction. Hybrid Unit 2: growth the output strength to follow the growth in PV energy. Therefore, it will help a larger proportion of the micro grid load call for. Hybrid Unit 3: since it operates as a stoop unit, this unit senses a lower inside the load, because of the increase inside the Hybrid Unit 2 output power. For this reason, with its output power decreasing, Hybrid Unit three will increase the frequency following its PV hunch slope. Hybrid Unit 2 follows the growing frequency to preserve regulating its output energy, which ends up within the slope alternate of the P=f point trajectory. This slope is determined by way of the PV stoop traits of Hybrid Unit three. At point C, the energy proscribing Controller in Hybrid Unit 2 reaches its running range restriction, and the unit starts off evolved working as a droop controlled unit, much like Hybrid Unit 3

.2) DC-DC Converters control actions: whilst the output energy of Hybrid Unit 3 decreases similarly into the PV phase, the battery DC-DC converter will increase the charging electricity to alter the DC-hyperlink voltage vdc. This reasons the charging strength to exceed the reference jPchj while the power limiting Controller is saturated at 0, and subsequently no longer lively. Therefore, the Charging Controller begins curbing PV electricity production by way of growing the PV array voltage reference vpv-ref using the controller PIB shown in Fig. 2. This control action slides the PV operating factor to a better voltage factor, far away from the MPP at the P-V curve of PV arrays. The curtailed PV power is diagnosed in Fig. 10 as laptop's he PIB loop begins adjusting vpv-ref, it generates manipulate alerts. The first is used to disable the most electricity point monitoring (MPPT) set of rules, and hold the MPP voltage (vmppt) consistent.

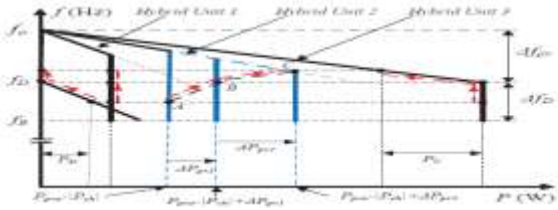


Fig. 10. P=f trajectories in response to increasing PV power that results in PV curtailment.

of the Power Limiting Controller using En = 0; Hld= 1,because the curtailed PV power does not represent the PV power limit anymore. Note that, this signal is always triggered after the Power Limiting Controller output has saturated and is no longer active. Therefore, the isolation of this controller will not result in any abrupt transients. The battery power PB tends to change in response to any variation in the load or the available PV power. Hence, the PIB continues to adjust the PV operating point accordingly, in order to regulate PB at the reference Pch. The output of the controller PIB decreases with the increasing load, and/or decreasing PV power, until it reaches zero. At this point, the PV converter resumes tracking the MPP again. This indicates that PH = Ppv □jPchj, and PC = 0. At the same point, the Power Limiting Controller is reconnected in response to the logic signal generated using the output of the PIB controller .The is cussed PV curtailment occurred in response to the increasing PV power at Hybrid Unit 2. A similar scenario happens due to a decreasing charging reference (jPchj). Moreover, PV curtailment occurs when the load drops below the PV Generation. This scenario can be explained similarly using the trajectories of the P=f operating points illustrated in Fig. 11.

C. Power Importing Scenario

The action of the Power Limiting Controller is equivalent to shifting down the PV droop line as illustrated by the dashed lines in Fig. 12. Accordingly, when PV ower keeps dropping, the hybrid unit reduces the output power, until the point when Ppv jPchj<0, and the hybrid unit starts importing power to support charging the battery, as the available PV power is insufficient to follow the charging reference.

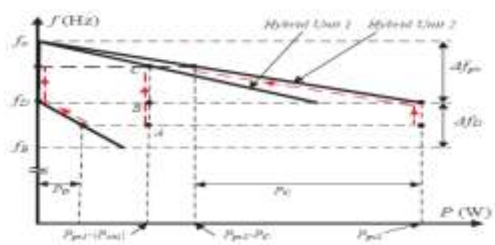


Fig. 11. P=f trajectories in response to decreasing load that results in PV Curtailment

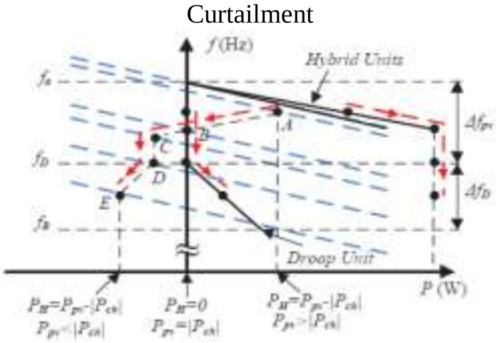
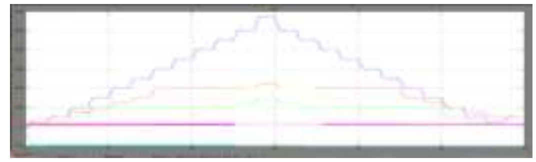


Fig. 12. P=f trajectory illustrating the strength importing state of affairs

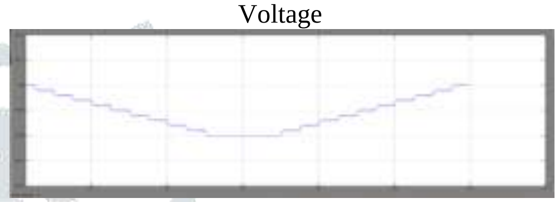
Segment CD, the hybrid gadgets restrict their output energy until the micro grid starts off evolved running in the stoop segment at factor D. Thereafter, the hybrid unit starts off evolved importing electricity from the hunch units.

Simulation Results USING PI CONTROLLER



Power

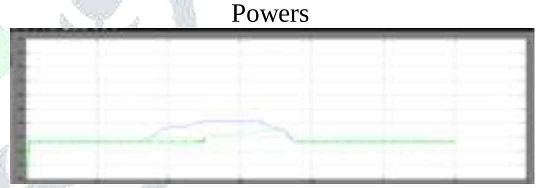
Voltage



FREQUENCY

Fig.13. Performance of the micro grid in response to variations in the load.

Powers



Pv voltage

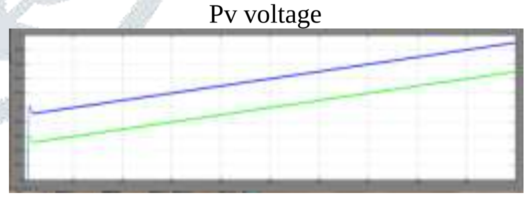


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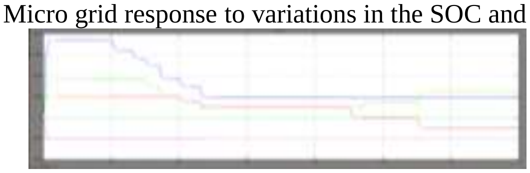
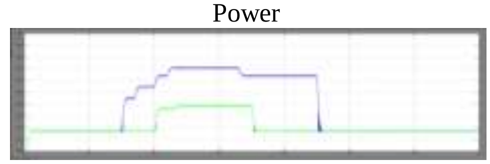
Fig14. Micro grid response to variations in the SOC and the load.



Power



Pv voltage

Fig.15 Micro grid response to solar irradiance and temperature variations.

CONTOLLER USING ANFIS:

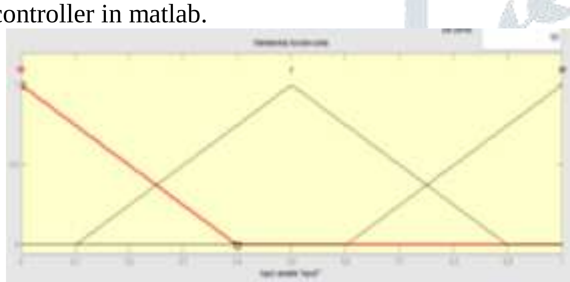
A fuzzy inference system and a back propagation algorithm. For an ordinary fuzzy inference, the parameters in the membership functions are usually determined by experience or the trial-and-error method. However, the adaptive neuro-fuzzy inference system can overcome this disadvantage through the process of learning to tailor the membership functions to the input/output data in order to account for these types of variations in the data values, rather than arbitrarily choosing parameters associated with a given membership function. This learning method works similarly to that of neural networks.

Adaptive Neural Fuzzy Inference System (ANFIS) is fuzzy Sugeno model put in the framework to facilitate learning and adaptation procedure. Such network makes fuzzy logic more systematic and less relying on expert knowledge. The objective of ANFIS is to adjust the parameters of a fuzzy system by applying a learning procedure using input–output training data. Basic architecture of ANFIS that has two inputs x and y and one output f.

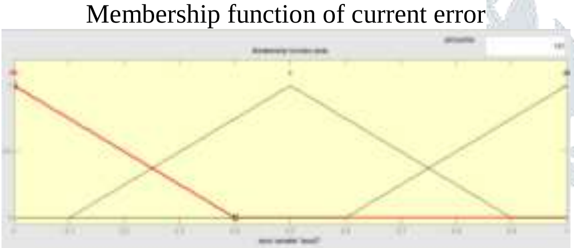
In Matlab the main difference between fuzzy controller and adaptive neuro fuzzy controller is only we have in Matlab two types fuzzy controllers one is Mamdani and second one is Sugeno.

Mamdani is ordinary fuzzy controller in this we provide input and output by using some assumptions but in Sugeno type we provide inputs only they automatically train outputs this is the main difference between two fuzzy controllers in Matlab.

So Mamdani type fuzzy controller used as ordinary fuzzy controller and Sugeno type fuzzy controller used as adaptive neuro fuzzy controller in matlab.



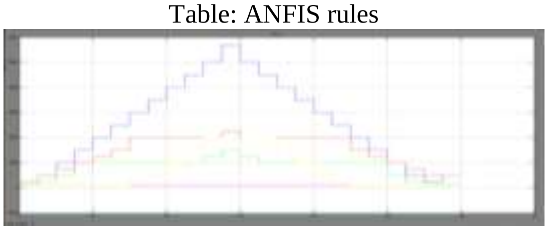
Membership function of current error



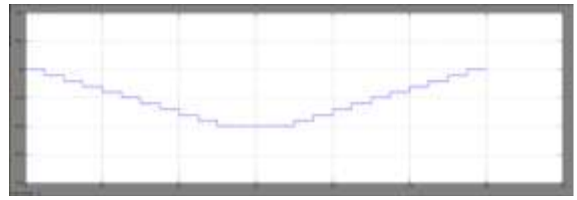
Membership function of change of current error

	NB	Z	PB
NB	NB	Z	NB
Z	Z	Z	Z
PB	NB	Z	PB

Table: ANFIS rules

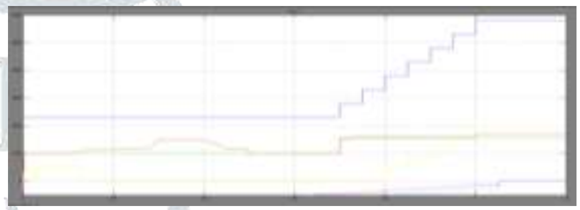


PowerVoltage



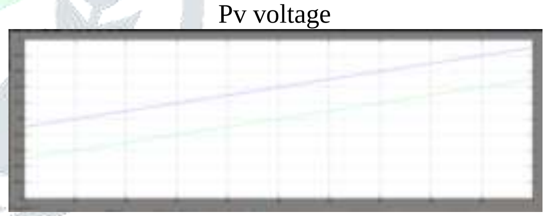
FREQUENCY

Fig.16 Performance of the micro grid in response to variations in the load.



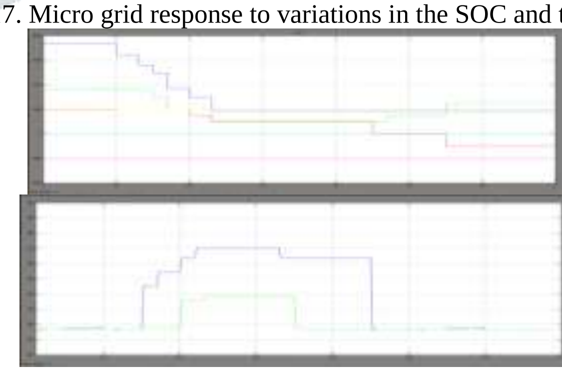
Power

Pv voltage



FREQUENCY

Fig.17. Micro grid response to variations in the SOC and the load



PowerPv voltage

Fig.18 Micro grid response to solar irradiance and temperature variations

VI.CONCLUSIONS

It's miles verified on this paper that decentralized electricity management of PV/battery hybrid units may be completed the use of nearby voltage controllers that comply with the proposed adaptive P=f feature curves. These curves are adjusted domestically at each unit in actual-time to evolve to diverse micro grid working situations. It is shown that the advanced approach can autonomously hold the strength balance inside the islanded microgrid, whilst making sure a coordinated operation of the batteries within the hybrid devices, without counting on any communications among distinct gadgets. The proposed approach has been confirmed the usage of an in depth switching model inside the MATLAB/SIMULINK environment.

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