System configuration of v-f control with solar PV generator operating at MPPT with a battery storage System

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***Abstract*— Microgrid concept allows small distributed energy resources (DERs) to act in a coordinated manner to provide a necessary amount of active power and ancillary service when required. This system proposes an approach of coordinated and integrated control of solar PV generators with the maximum power point tracking (MPPT) control and battery storage control to provide voltage and frequency (V-f) support to an islanded microgrid. Also, active and nonactive/reactive power (P-Q) control with solar PV, MPPT and battery storage is proposed for the grid connected mode. The control strategies show effective coordination between inverter V-f (or P-Q) control, MPPT control, and energy storage charging and discharging control. The system also shows an effective coordination among participating micro resources while considering the case of changing irradiance and battery state of charge (SOC) constraint. The simulation studies are carried out with the IEEE 13-bus feeder test system in grid connected and islanded microgrid modes. The results clearly verify the effectiveness of proposed control methods. The simulations are carried out in Matlab and Sim power systems.**

***Index Terms*— Microgrid, Distributed Energy Resources (DERs), Maximum Power Point Tracking (MPPT), State of Charge (SOC), Power Control, Solar Power.**

I. INTRODUCTION

The microgrid could be a assortment of distributed generators or micro resources, energy storage devices, and hundreds that operate as one and freelance governable system capable of providing each power and warmth to the realm of service. The micro resources that are incorporated during a microgrid are comprised of tiny units, but one hundred power unit, supplied with power natural philosophy (PE) interface. Commonest resources are star electrical phenomenon (PV), electric cell (FC), or micro turbines connected at the distribution voltage level. During a microgrid, the micro sources and storage devices are connected to the feeders through the micro source controllers (MCs) and also the coordination among the micro sources is allotted by the central controller (CC).

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The microgrid is connected to the medium voltage level utility grid at the point of common coupling (PCC) through the circuit breakers. Once a microgrid is connected to the grid, the operational management of voltage and frequency is finished entirely by the grid; but, a microgrid still provides the vital hundreds at PCC, thus, acting as a PQ bus. In islanded condition, a microgrid must operate its own, freelance of the grid, to manage the voltage and frequency of the microgrid and thus, acts sort of a PV (power-voltage) bus. The operation and management in each the modes is controlled and coordinated with the assistance of micro source controllers (MCs) at the native level and central controller (CCs) at the worldwide level. Almost like the standard synchronous generator frequency management, the microgrid voltage and frequency management may be performed mistreatment droop management ways.

The present work provides quick response characteristics for voltage and frequency management as compared to the secondary management thought-about. The Analogy between electrical converter management and also the synchronous generator management in an islanded microgrid is studied intimately. Within the islanded mode, there's the need of getting a reference voltage and frequency signals within the microgrid electrical converter management. The operation and management of the electrical converter interface of renewable primarily based distributed energy resources (DERs), like star electrical phenomenon (PV) during a microgrid, could be a real challenge, particularly once it involves maintaining each microgrid voltage and frequency at intervals a suitable vary. A voltage management technique supported ancient droop management for voltage sag mitigation together with voltage ride through capability is planned.

A dynamic voltage regulation supported adaptive management is projected. However, there don't seem to be several analysis works performed on V-f or P-Q management victimization star PV together with MPPT management and battery storage in microgrids. In frequency regulation with PV in microgrids is studied; but, this work doesn't contemplate the voltage management objective and lacks battery storage within the microgrid. In an exceedingly tiny scale PV is taken into account in an exceedingly grid-connected mode to manage the active and reactive power of the system.

Here, the management strategies think about abc-dq0 transformation and the other way around that is avoided within the gift system. In power modulation of star PV generators with an electrical double layer capacitance as energy storage is taken into account for frequency management. In load frequency management is enforced in microgrid with PV and storage; but, this work additionally lacks the thought of a voltage management objective. The voltage associate degreed frequency management with star PV and battery in microgrid with an induction machine is investigated; but, this work doesn't make a case for the transfer mechanism of controls to contemplate the battery SOC constraint. In summary, the previous works during this topic either lack the incorporation of associate degree energy storage element or the voltage management objective together with frequency management or the incorporation of management transition in several situations. The current work fulfills these gaps by considering all of those objectives. P2P streaming systems can be broadly classified into two categories based on the overlay network structure. They are tree-based and mesh-based. The tree-based systems, such as ESM, have well-organized overlay structures and typically distribute video by actively pushing data from a peer to its children peers. One major drawback of tree-based streaming systems is their vulnerability to peer churn. A peer departure will temporarily disrupt video delivery to all peers in the subtree rooted at the departed peer. In a mesh-based P2P streaming system, peers are not confined to a static topology. Instead, the peering relationships are established or terminated based on the content availability and bandwidth availability on peers. A peer dynamically connects to a subset of random peers in the system. Peers periodically exchange information about their data availability. Video content is pulled by a peer from its neighbors who have already obtained the content. Since multiple neighbors are maintained at any given moment, mesh-based video streaming systems are highly robust to peer churns. However, the dynamic peering relationships make the video distribution efficiency unpredictable. Different data packets may traverse different routes to users. Consequently, users may suffer from video playback quality degradation ranging from low video bit rates, long startup delays, to frequent playback freezes.

In the rest of the article we give a survey on the existing P2P media streaming systems. The P2P live streaming systems are described first in Section 2, followed by the P2P video-on-demand systems in Section 3. You will see how different design requirements influence the system architectures. Within each section, representative systems are used as examples to show both tree-based and mesh-based system architectures.

II. Literature Survey

Literature survey is the most important step in software development process. Before developing the tool it is necessary to determine the time factor, economy and company strength. Once these things are satisfied, then the next step is to determine which operating system and language can be used for developing the tool. Once the programmers start building the tool the programmers need lot of external support. This support can be obtained from senior programmers, from book or from websites. Before building the system the above consideration are taken into account for developing the proposed system.

The major part of the project development sector considers and fully survey all the required needs for developing the project. For every project Literature survey is the most important sector in software development process. Before developing the tools and the associated designing it is necessary to determine and survey the time factor, resource requirement, man power, economy, and company strength. Once these things are satisfied and fully surveyed, then the next step is to determine about the software specifications in the respective system such as what type of operating system the project would require, and what are all the necessary software are needed to proceed with the next step such as developing the tools, and the associated operations.

Energy in electrical kind, excluding being clean, is generated (converted from different natural forms) centrally in bulk; is simply controlled; transmitted efficiently; and it's easily and expeditiously pliable to different types of energy for varied industrial and domestic applications. It's thus a sought after variety of energy and is a vital ingredient for the commercial and well-rounded development of any country. The generation of current (by changing different naturally on the market types of energy), dominant of current, transmission of energy over long distances to different load centers, and distribution and utilization of current along is called Associate in Nursing electric power system. The scheme that generates current is named generation scheme or generating plants (stations). It consists of generating units (consisting of turbine- generator sets) as well as the required accessories. Speed governors for the prime movers (turbines; exciters and voltage regulators for generators, and increase transformers also kind a part of the generating plants. The scheme [3] that transmits the current over long distances (from generating plants to main load centers) is named transmission scheme. It consists of transmission lines, control transformers and static/rotating volt-ampere units (which area unit accustomed management active/reactive powers). The sub system that distributes of energy from load centers to individual client points along with finish energy changing devices like motors, resistances etc., is called distribution subsystems. It consists of feeders, change of magnitude transformers, and individual consumer connections together with the terminal energy changing electrical instrumentation such as motors, resistors etc. Electrical energy cannot be hold on economically and therefore the electrical utility will exercise very little control over the load demand (power) at any time. The ability system should, therefore, be capable of matching the output from the generators to demand at any time at such voltage and frequency. With the constant increase within the current demand, a lot of and a lot of generating units, the transmission lines and distribution network together with the required dominant and protecting circuits build the ability system an oversized advanced system. It's thought of as one of the most important artificial systems. Therefore extremely trained engineers area unit required to develop and implement the advances of technology for designing, operation and management of power systems.

The MicroGrid construct assumes a cluster of hundreds and micro sources (<100 kW) operative as one governable system that has each power and warmth to its native space. This idea provides a replacement paradigm for outlining the operation of distributed generation. To the utility the MicroGrid may be thought of as a controlled cell of the facility system. For instance this cell may be controlled as one dispatchable load, which may respond in seconds to fulfill the wants of the gear. To the client the MicroGrid may be designed to fulfill their special needs; like, enhance native reliableness, cut back feeder losses, support native voltages, give raised potency through use waste heat, voltage sag correction or give uninterruptible power provide functions. This paper [1] provides a summary of the MicroGrid paradigm. This includes the fundamental design, management and protection and energy management.

It's a two-stage configuration wherever a DCDC boost device is employed for MPPT management. The system [2] also considers electric battery back-up just in case of emergencies while maintaining the voltage and frequency of the small grid or whereas making an attempt to produce the vital hundreds. Electric battery is connected in parallel to the PV to inject or absorb active power through a biface DC-DC device. When the battery is interesting power, the device operates within the buck mode and once battery is injecting power to the grid, it operates within the boost mode. The operation mode is maintained through the management signal provided to the converter switches.

This paper [4] describes and evaluates the feasibleness of management methods to be adopted for the operation of a microgrid once it becomes isolated. Normally, the microgrid operates in interconnected mode with the medium voltage network; but, scheduled or forced isolation will happen. In such conditions, the microgrid should have the power to work stably and autonomously. Associate analysis of the requirement of storage devices and cargo shedding methods is enclosed during this paper.

This paper [5] discusses a digital management strategy for three-phase pulse-width modulation voltage inverters employed in a single complete ac distributed generation system. The planned control strategy utilizes the right strong serve problem management theory to permit elimination of nominative unwanted voltage harmonics from the output voltages beneath severe nonlinear load and to realize quick recovery performance on load transient. This technique is combined with a distinct slippery mode current controller that gives quick current limiting capability necessary under overload or contact conditions. The planned management strategy has been enforced on a digital signal processor system and AN experiment} tested on an 80-kVA image unit. The results showed the effectiveness of the planned management formula.

The management theme is primarily based on the droop technique, and it uses some calculable variables from the grid such as the voltage and the frequency, and the magnitude and angle of the grid resistivity. Hence, the electrical converter is ready to inject severally active and reactive power to the grid. The controller provides [6] a correct dynamics decoupled from the grid resistivity. Simulation results are provided so as to point out the practicableness of the management projected.

III. Proposed Approach

This system proposes several control algorithms through which the capability of PV generators for voltage and frequency (V-f) control and active and nonactive/reactive power (P-Q) control in islanded and grid connected microgrids could be harnessed. Detailed models of PV, battery, inverter and converter are considered for the study. The major contribution and novelty of the proposed control methods lie in the coordination among individual proposed control methods: MPPT control at the PV side, battery control, and V-f/P-Q control algorithm at the inverter side. These three control algorithms at three stages are jointly linked through a power balance objective at the DC and AC side of the inverter so that the DC side voltage is indirectly controlled at the desired value in order to maintain the AC side voltage at the utility desired voltage.

Also, the proposed control methods have the capability of handling battery state of charge (SOC) constraints through the coordination of controls between participating micro resources in the microgrid. This is a very important contribution from this work as compared to other literatures in this area. At the same time, the controls can seamlessly transform from one mode e.g., inverter P-Q control in grid connected mode to V-f control in islanded mode. The proposed control methods are validated with satisfactory results. The controls are developed in abc reference frames using the RMS/average values of voltages and active and reactive power

Hence, it is easy and efficient to implement, and avoids the transformation to and from other reference frames which greatly simplifies the control strategies. The chosen control parameters in the proposed methodologies are, however, dependent on the PV, battery, and external power grid conditions. These parameters can be adaptively achieved with the changing system conditions which could be a very promising future direction of this work. The rest of the system is organized as follows: Following descriptions briefly presents the analytical modeling of Solar PV with model validation results. The PV system configuration, describes the modeling of the battery storage, and provides information about the structure of IEEE 13-bus distribution feeder under study. Section V describes the proposed coordinated V-f and P-Q control algorithms while incorporating PV MPPT control and battery storage control.

IV. System Architecture

The major part of the project development sector considers and fully survey all the required needs for developing the project. Generally algorithms shows a result for exploring a single thing that is either be a performance, or speed, or accuracy, and so on. An architecture description is a formal description and representation of a system, organized in a way that supports reasoning about the structures and behaviors of the system. System architecture can comprise system components, the externally visible properties of those components, the relationships (e.g. the behavior) between them.

The traditional synchronous generator frequency control, the microgrid voltage and frequency control can also be performed using droop control methods. In past systems, a small scale PV is considered in a grid-connected mode to control the active and reactive power of the system. The voltage and frequency control with solar PV and battery in microgrid with an induction machine is investigated in earlier systems; however, this work does not explain the transfer mechanism of controls to consider the battery SOC constraint. For all the past systems either lacks the incorporation of an energy storage component or the voltage control objective along with frequency control or the incorporation of control transition in different scenarios.

- The major contribution and novelty of the proposed control methods lie in the coordination among individual proposed control methods: MPPT control at the PV side, battery control, and V-f/P-Q control algorithm at the inverter side.
- These three control algorithms at three stages are jointly linked through a power balance objective at the DC and AC side of the inverter so that the DC side voltage is indirectly controlled at the desired value in order to maintain the AC side voltage at the utility desired voltage.
- Also, the proposed control methods have the capability of handling battery state of charge (SOC) constraints through the coordination of controls between participating micro resources in the microgrid.

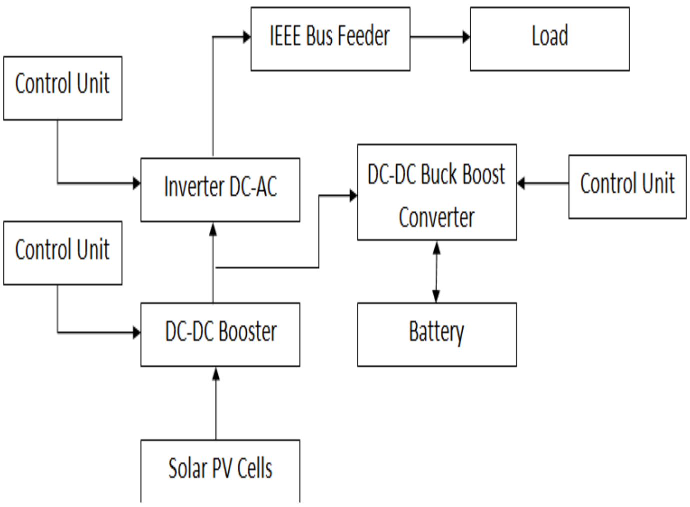

Fig 1: Block Diagram

V. IMPLEMENTATION

Following are the most frequently used project management
Methodologies in the project management practice:

1. PV System Configuration
2. Battery Modeling
3. Description of IEEE 13-Bus distribution Feeder
4. MPPT and Battery Integrated V-F Control Method

5.1 PV System Configurations

Fig. 2 shows the PV system configuration for V-f and P-Q control with PV operating at MPP including the battery storage backup. It is a two-stage configuration where a DC-DC boost converter is used for MPPT control. The system also considers a battery back-up in case of emergencies while maintaining the voltage and frequency of the microgrid or while trying to supply the critical loads.

A battery is connected in parallel to the PV to inject or absorb active power through a bidirectional DC-DC converter. When the battery is absorbing power, the converter operates in the buck mode and when battery is injecting power to the grid, it operates in the boost mode. The operation mode is maintained through the control signal provided to the converter switches. The PV system is connected to the grid through a coupling inductor. The coupling inductor filters out the ripples in the PV output current. The connection point is called the point of common coupling (PCC) and the PCC voltage is denoted.

The PV source is connected to the DC link of the inverter with a capacitor. The PV is the active power source, and the capacitor is the reactive power source of the PV system. According to the instantaneous power definitions, for a balanced three-phase system, if and denote the instantaneous PCC voltage and the inverter output voltage (harmonics neglected), respectively, then the average power of the PV denoted as, the apparent power and the average reactive power of the PV.

5.2 Battery Modeling

In this system, the battery model is taken from the MATLAB Sim Power Systems library with appropriate parameters which will be used for the proposed V-f and P-Q controls. The detailed description about the battery model is given. Due to the intermittent and uncertain nature of solar power output and also the highly fluctuating load demands, deep cycle lead acid batteries are the most common type of battery storage in microgrid applications because the maximum capacity of the battery can be utilized. Hence, in this system, a battery is modeled as a lead acid battery with appropriate choice of parameters for deep cycle application. It is assumed that the lead acid battery can be discharged up to SOC of 20% and can be charged up to SOC of 80%.

The battery model is an analytical model with two equations representing the battery discharge and charge models. In this model, the term for polarization voltage and polarization resistance is considered to model the Open Circuit Voltage (OCV) of the battery more accurately. The term inside the first square bracket in (10) represents the polarization resistance and the second square bracket represents the polarization voltage. The size of the battery is selected to provide a maximum backup power to compensate for the PV generation in the case of a very small or no irradiance level. In this work, the MPP of PV generator at STC is 100 kW. Hence, the battery is chosen to provide this amount of power for a maximum of 1 hour with an energy content of 100 kWh. The battery backup is considered for short duration applications like frequency control and supplying power to critical loads in the event of emergency situations. One hour of battery backup is considered to be enough for other backup generators to take over the controls in the microgrid emergency situations.

5.3 Description of IEEE 13-Bus Distribution Feeder

It consists of a substation, 13 buses or nodes, 11 line sections, and 8 loads. The loads comprise of a combination of constant impedance, constant current, and constant power (ZIP) loads but most of them are constant power loads. The substation is at 115 kV and it is stepped down to 4.16 kV by a distribution transformer (T1).

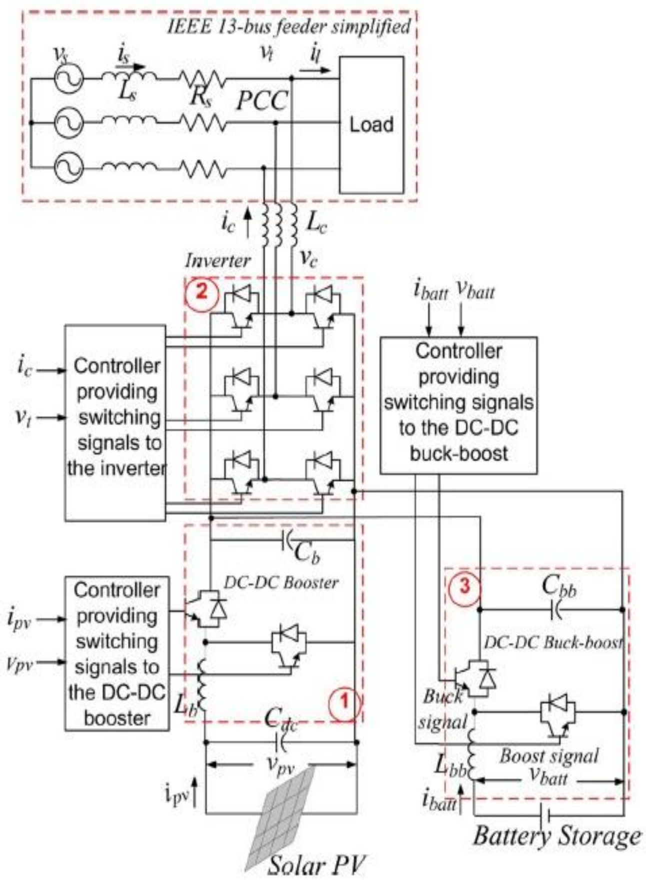

Fig 2: System Configuration of V-F Control with Solar PV generator operating at MPPT with a battery storage system.

There is one more transformer (T2) which steps down 4.16 kV to 480 V. In the grid connected mode, the substation located at Bus 650 at 115 kV level is considered as a source. In an islanded microgrid case, a diesel generator connected at the same bus supplies the microgrid with a fixed amount of active power as referenced by the central controller (CC) of the microgrid.

5.4 MPPT and Battery Integrated V-F Control Method

The control comprises of one loop for MPPT control, two different loops for V-f control at the inverter side and another loop for battery power management. The loop1 is a MPPT control at the PV array side which uses the reference MPP, from the look up table of irradiance versus MPP. Then, it compares the actual PV power output, with this reference and feeds this error to a PI controller, which outputs the duty cycle for the DC-DC booster so that the array always operates at the referenced point. Another feedback PI controller is used for voltage control at AC side. As shown in the control diagram (loop 2), the PCC voltage is measured and the rms value of is calculated. Then, the rms value is compared to a voltage reference which could be a voltage specified by the utility, and the error is fed to a PI controller. The inverter output voltage is controlled so that it is in phase with the PCC voltage, and the magnitude of the inverter output voltage is controlled so that the PCC voltage is regulated at a given level.

In 1 has been added to the right-hand side such that when there is no injection from the PV generator, the PV output voltage is exactly the same as the terminal voltage. The frequency control is carried out by controlling the active power output at the inverter side as shown in the outermost loop 3. The referenced microgrid frequency of 60 Hz is compared with the measured value and this error is fed to the PI controller that provides the phase shift contribution which shifts the voltage waveform in timescale such that the active power injected will be enough to maintain the frequency at 60 Hz nominal value.

There is another controller used in the same loop 3. This controller maintains active power balance between the AC and DC sides of the inverter. The reference signal for is obtained from the dynamically changing active power injection from the inverter at the AC side as determined by the output. The measured AC side active power is multiplied by a factor of 1.02 considering the efficiency of inverter as 98% such that the DC side active power is 102% of the AC side active power. Here, the reason behind considering phase shift contributions from both DC and AC side active power is to control the DC side voltage and achieve the desired value. By making and close in range through the controller gains, it can be assured that the active power at the DC and AC sides is balanced. This, coupled with the voltage control loop, assures that the DC side voltage is maintained at the value desired by the AC side voltage. The battery is incorporated in the PV system configuration in order to supply or absorb active power and support the frequency control objective with the PV generator. If there is abundant solar power and the active power required for frequency control is less than PV MPP, then the battery will be charged.

If there is not enough solar power available and if the active power required for frequency control is more than PV MPP, then the battery will supply the deficit power in order to maintain the microgrid frequency at 60 Hz. Hence, the control method for the battery charge/discharge that depends on this requirement is developed. It also shows the selection of charge and discharge modes which handle the battery SOC constraint and will be described later in the Part B of this section. The reference power to the battery is generated dynamically by subtracting the inverter active power injection, from the power generated.

The controller comprised of a PI controller, which receives the error signal obtained after subtracting the actual battery power, from the battery reference. The signal obtained from is then compared with a triangular waveform of unity magnitude to generate the signal. This is similar to common Pulse Width Modulation (PWM) in inverter controls. And are the proportional and integral gains respectively. One more step is considered to differentiate the charging and discharging mode of the battery. This is undertaken by comparing with. If, the battery is in charging mode, hence, the signal obtained from the PWM, and the result of this comparison is passed through a logical AND to generate a switching signal which activates the Buck mode of the DC-DC converter. If the condition is false, (i.e.,), the opposite of this signal and is passed through a logical AND to generate a switching signal which activates the Boost mode of the DC-DC converter. Hence, with this control logic, the converter is capable of operating in both directions and therefore, effectively charging and discharging the battery whenever required. This will be verified through the results presented.

VI. CONCLUSION

This system proposes and presents coordinated strategies of V-f control and P-Q control, respectively, for microgrids with PV generator and battery storage. In the control strategies, the PV generator is operated at MPP, and the battery storage acts as a buffer in order to inject and absorb deficit or surplus power by using the charge/discharge cycle of the battery. The system contributes in demonstrating the control strategies with effective coordination between inverter V-f (or P-Q) control, MPPT control, and energy storage control. The proposed control strategy also provides a smooth transition of PV side PQ control in grid connected mode to V-f control in islanded mode. This is the most essential feature required in the modern microgrid controllers. The proposed control algorithms are also capable of handling the battery SOC constraint. An effective seamless transformation of controls from V-f to constant active power and voltage control at the PV side and from constant active power control to frequency control at the diesel generator is validated with satisfactory results. This feature helps the controller to adapt to the changing irradiance levels while considering the battery availability. The proposed V-f control method shows a very satisfactory performance in reviving highly reduced voltage and frequency back to the nominal values in a matter of only 2 seconds. It is much faster than the diesel generator control which takes around 10 seconds to settle down. Hence, PV and battery installations might be applied effectively in restoring the microgrid frequency and the voltage at PCC after disturbances. Similarly, the proposed integrated and coordinated P-Q control algorithm can be effectively used in supplying some critical loads of a microgrid with solar PV and battery. In the present methods, the control parameters are dependent upon the PV, battery, and external grid conditions and must be re-tuned with the changing conditions. This can be overcome by using an adaptive method to obtain these parameters dynamically based on the system conditions. The adaptive control methods could be a very useful and promising future direction of this work.

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