IPHV8I1066X
International Journal Of Advanced Research and Innovation -Vol.8, Issue .I
ISSN Online: 2319 – 9253
Print: 2319 – 9245

COORDINATION CONTROL AND PROTECTION OF PHOTOVOLTAIC HYBRID AC - DC SMART GRID

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ABSTRACT: The hybrid AC - DC micro grid with renewable energy (i.e. Solar Energy, energy storage as battery banks) for the integration of a pulse load. AC - DC micro grid works in islanding with a synchronous generator and photovoltaic panel by this photovoltaic panel, the power is supplying to the systems AC and DC sides respectively. The active and reactive power flow is controlling in between the AC and DC sides by a bidirectional through the link. The photovoltaic panel is connected to the DC bus through a DC - DC boost converter and a battery bank is connected to the DC bus through a bidirectional DC - DC converter. The battery bank injects or observes energy on the DC bus to regulate the DC side voltage. The frequency and voltage of the AC side are regulated by a bidirectional three phase AC – DC inverter. The power flow control of these devices serves to increase the system as stable. A coordination power flow control method of multi power electronic devices AC – DC micro grid with the control algorithm can greatly increase the system efficiency stability and robustness when operated in islanding model. This has simulated using MATLAB/Simulink.

Keywords: *Energy storage, grid control, hybrid micro grid, PV system, frequency and voltage amplitude regulation.*

I. INTRODUCTION

As electric distribution technology steps into the next century, many trends are becoming noticeable that will change the requirements of energy delivery. These modifications are being driven from both the demand side where higher energy availability and efficiency are desired and from the supply side where the integration of distributed generation and peaks having technologies must be accommodated.

Power systems currently undergo considerable change in operating requirements mainly as a result of deregulation and due to an increasing amount of distributed energy resources (DER). In many cases DERs include different technologies that allow generation in small scale (micro sources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having micro sources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. Moreover, the possibility of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (in Europe 230 V and in the USA 110 V) is diminished since adjacent micro sources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances. This is identified nowadays as a microgrid. The distinctive microgrid has the similar size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographic span of 1 km. Generally more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The microgrid often psupplies both electricity and heat to the customers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels. The storing device in the microgrid is equivalent to the rotating reserve of large generators in the conventional grid which ensures the balance between energy generation and consumption especially during rapid changes in load or generation.

II. MICRO GRIDS

It is a small-scale power supply network that is designed to provide power for a small community. It enables local power generation for local loads. It comprises of various small power generating sources that makes it highly flexible and efficient. It is connected to both the local generating units and the utility grid thus preventing power outages. Excess power can be sold to the utility grid. Size of the Microgrid may range from housing estate to municipal regions.

Protection system is one of the major challenges for microgrid which must react to both main grid and microgrid faults. The protection system should cut off the microgrid from the main grid as rapidly as necessary to protect the microgrid loads for the first case and for the second case the protection system should isolate the smallest part of the microgrid when clears the fault. A segmentation of microgrid, i.e. a design of multiple islands or submicrogrids must be supported by micro source and load controllers. In these conditions problems related to selectivity (false,

ISSN Online: 2319 – 9253
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unnecessary tripping) and sensitivity (undetected faults or delayed tripping) of protection system may arise.

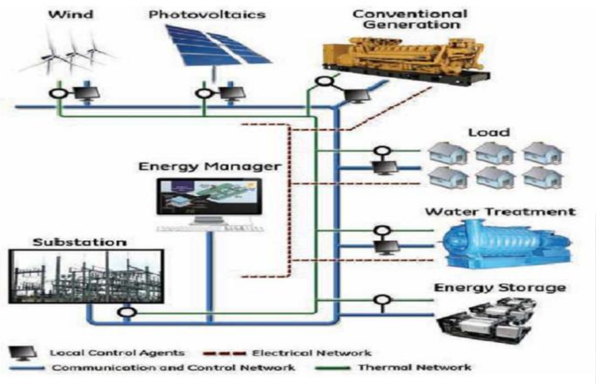

Fig 1 Microgrid power system

In such situations a loss of relay coordination may happen and generic OC protection with a single setting group may become insufficient, i.e. it will not guarantee a selective operation for all possible faults. Hence, it is vital to ensure that settings chosen for OC protection relays take into account a grid topology and changes in location, type and amount of generation. Otherwise, unwanted operation or failure may occur during necessary condition. To deal with bi-directional power flows and low short-circuit current levels in microgrids dominated by micro sources with power electronic interfaces a new protection philosophy is essential, where setting parameters of relays must be checked/updated periodically to make sure that they are still appropriate.

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Island Mode

Utility grid is not supplying power,Static switch is open, Feeder A, B, C is being supplied by Micro sources, Feeder D (not sensitive) is dead.

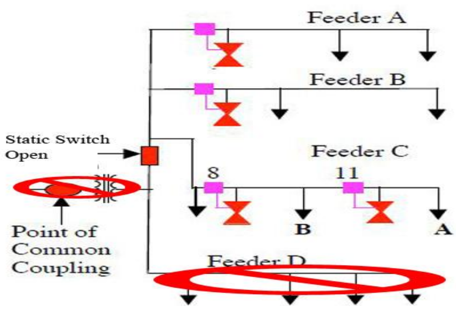


Fig 2 Islanded Mode

Application of individual distributed energy resources, DER, can cause as many problems as it may solve. A better way to realize the emerging potential of distributed energy resources is to take a system approach viewing DER and associated loads as a grid resource or a “microgrid”. The sources and loads can operate in parallel to the grid or as an island. It can provide for the customer’s critical needs while providing services to the distribution system.

III. PHOTOVOLTAIC SYSTEM

A photovoltaic system makes use of one or more solar panel electricity. It consists of various components which include the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.

The basic ingredients of PV cells are semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer creates an electric field, on one side positive and negative on the other. When light energy hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material. When electrical conductors are connected to the positive and negative sides an electrical circuit is formed and electrons are captured in the form of an electric current that is, electricity. This electricity is used to power a load. A PV cell can either be circular or square in construction.

The photovoltaic system can generate direct current electricity without environmental impact when is exposed to sunlight. The basic building block of PV arrays is the solar cell,

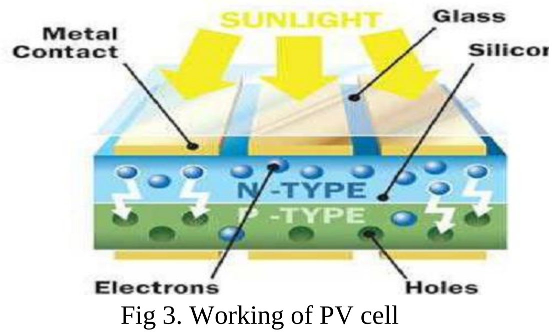


Fig 3. Working of PV cell

which is basically a p-n junction that directly converts light energy into electricity. The output characteristic of PV module depends on the cell temperature, solar irradiation, and output voltage of the module. The figure shows the equivalent circuit of a PV array with a load.

Maximum Power Point Tracking

As an electronic system maximum power point tracker (MPPT) functions the photovoltaic (PV) modules in a way that allows the PV modules to produce all the power they are capable of. It is not a mechanical tracking system which moves physically the modules to make them point more directly at the sun. Since MPPT is a fully electronic system,

ISSN Online: 2319 – 9253
Print: 2319 – 9245

it varies the module's operating point so that the modules will be able to deliver maximum available power. As the outputs of PV system are dependent on the temperature, irradiation, and the load characteristic MPPT cannot deliver the output voltage perfectly. For this reason MPPT is required to be implementing in the PV system to maximize the PV array output voltage.

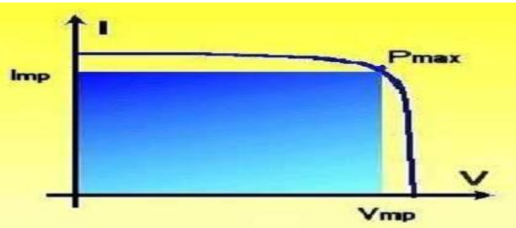


Fig 2.5. MPP characteristic

In the power versus voltage curve of a PV module there exists a single maxima of power, i.e. there exists a peak power corresponding to a particular voltage and current. The efficiency of the solar PV module is low about 13%. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and irradiation conditions. This maximized power helps to improve the use of the solar PV module. A maximum power point tracker (MPPT) extracts maximum power from the PV module and transfers that power to the load. As an interfacing device DC/DC converter transfers this maximum power from the solar PV module to the load. By changing the duty cycle, the load impedance is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

IV. PROPOSED CONCEPT

The hybrid micro grid configuration where the Synchronous generator, PV farm, and loads are connected to its Corresponding AC and DC sides.

The AC and DC slinked through a bidirectional three phase AC-DC inverter and Transponder this paper focuses on islanding mode operation so the coordination control of power electronics devices operating in grid connected mode are not discussed. The proposed system works in islanding mode but can operate in grid Connected mode if the AC bus is tied to the utility grid.

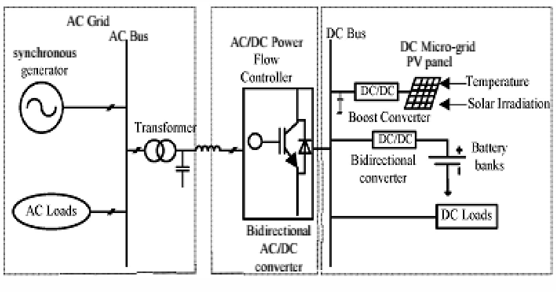


Fig3.1 Hybrid AC-DC micro grid power system.

The Matlab Simulink model shown in Fig is used to system operations under different circumstances. A 10 kW PV farm is connected to the DC bus as the DC source through a DC-DC boost converter with MPPT functionality. A 50 Ah lithium-ion battery with 108V tensional voltage is connected to the DC bus through a bidirectional DC-DC boost converter to regulate the DC bus voltage. A synchronous three generator with 13.8 kVA and 208V phase to phase nns terminal voltage is connected to the AC side. The rated voltages for DC and AC sides are 340 V and 208V phase to phase rms, respectively. A 15 kW pulse load is connected to AC and DC sides, respectively.

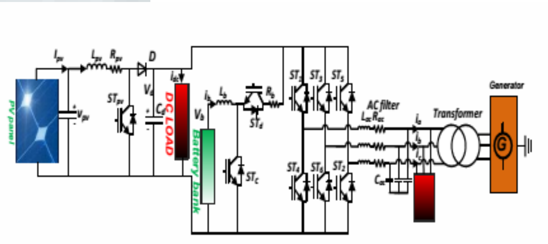


Fig3.2 The compact Matlab Simulink model of the proposed micro grid

An accurate battery cell model is needed to regulate the DC bus voltage in islanding mode.

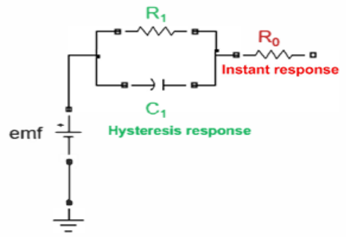


Fig3.4 Lithium-ion battery equivalent circuit

The battery terminal voltage and SOC need to be estimated during operation. A high Fidelity electrical model of lithium-ion battery model with Thermal dependence is used. The equivalent circuit of the Battery model is shown in Fig3.4 The instantaneous response modeled by a resistor Ro and the hysteresis response is Modeled by a non-linear RC circuit R/ and C/. Emf represents the internal voltage of the battery.

All four parameters are varying with different sacs and temperatures, so four lookup tables are established by using the parameter estimation Too box in Simulink Design Optimization for these four Parameters under different sacs and temperatures. The flow Diagram of the parameter estimation procedure is shown in Fig The SOC of each single battery cell can be calculated by equation

$$SOC = 100(1 + \frac{\int i_b dt}{Q})$$

The frequency and voltage amplitude of the three phase AC side is not fixed during islanding operation so a device is Needed to regulate these variables. A bi-directional AC-

DC inverter is used with the active and reactive power decoupling technique to keep the AC side stable. The Control scheme for the bi-directional AC-DC inverter is shown in Fig. 8. in d-q cord mates, Id IS controlled to regulate the active power flow Through the inverter to regulate the AC side frequency, and Iq is Controlled to regulate the reactive power flow through the Inverter to regulate the AC side voltage amplitude. Multi-loop control is applied for both frequency and Voltage regulation. For frequency control, the error between measured frequency and reference frequency is sent to a PI Controller which generates the id reference. To control the Voltage amplitude, the error between the measured voltages amplitude and the reference voltage amplitude is sent to a PI Controller to generate iq reference. Equations show The AC side voltage equations of the bi-directional AC-DC Inverter in ABC and d-q coordinate respectively. Where (Va, Vb, Vc) are AC side voltages of the inverter, and (Ea, Eb, Ee) are the voltages of the AC bus. (Lla, LIb, LIe) are the adjusting signals After the PI controller in the current control loop.

$$L_{ac}\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + R_{ac}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} - \begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} + \begin{bmatrix} \Delta_a \\ \Delta_b \\ \Delta_c \end{bmatrix}$$

$$L_{ac}\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} -R_{ac} & \omega L_{ac} \\ -\omega L_{ac} & -R_{ac} \end{bmatrix}\begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} V_d \\ V_q \end{bmatrix} - \begin{bmatrix} E_d \\ E_q \end{bmatrix} + \begin{bmatrix} \Delta_d \\ \Delta_q \end{bmatrix}$$

When the pulse load is connected or disconnected to the AC side, the frequency or the voltage amplitude will be altered. After detecting the variance from the phase lock loop (PLL) or voltage transducer, Id and Iq reference signals will be adjusted to regulate power flow through the bi-directional AC-DC Inverter. Because of the power flow variances, the DC bus Voltage will also be influenced. The DC bus voltage transistor will sense the voltage variance in the DC bus, and the bidirectional DC-DC converter will regulate the current flow Between the battery and the DC bus. In the end, the energy is transferred between the battery and the AC side to balance the Power flow in the system.

V.MATLAB/SIMULINK RESUTS

Case i: *The proposed micro grid with pulse load variation without DC support.*

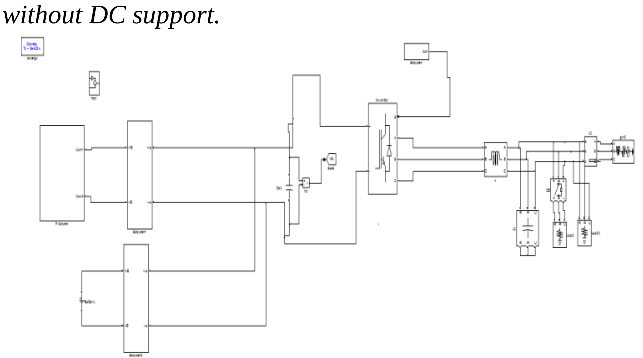


Fig.Matlab Simulink model of the proposed micro grid

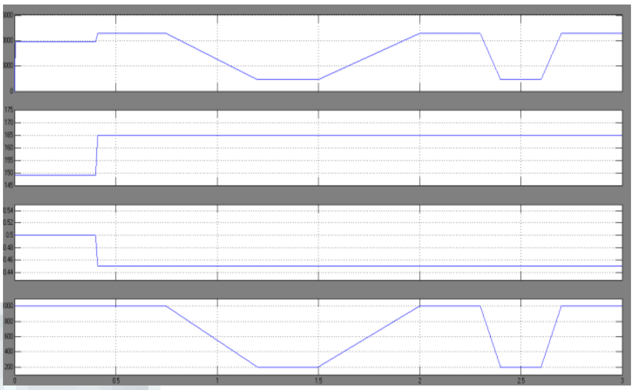
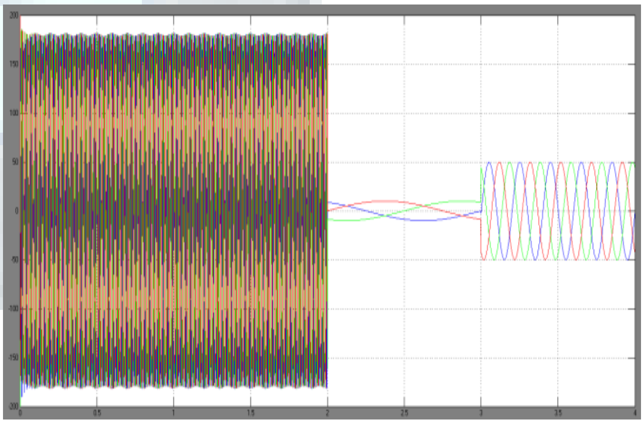


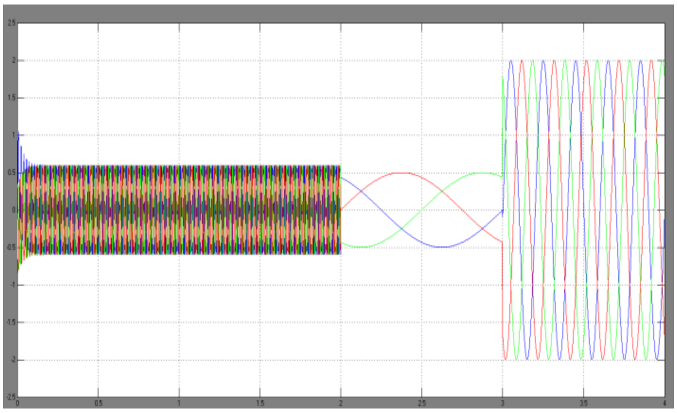
Fig.9. PV farm output power control with MPPT.

Fig.10. DC bus voltage with the influence of solar irradiance variation and pulse load



(a) Ac Bus voltage with Pulse load influence.

(b)



(b). Ac Bus Current with Pulse load influence.

IPHV8I1066X
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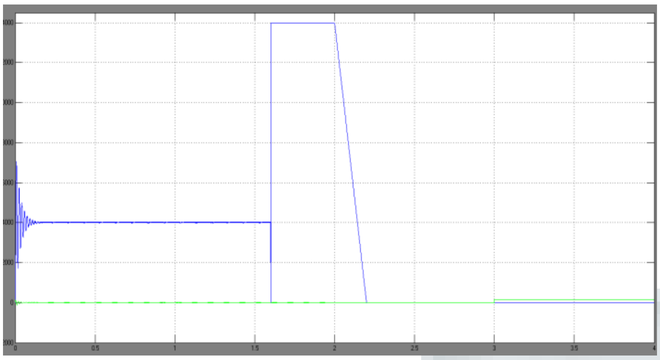
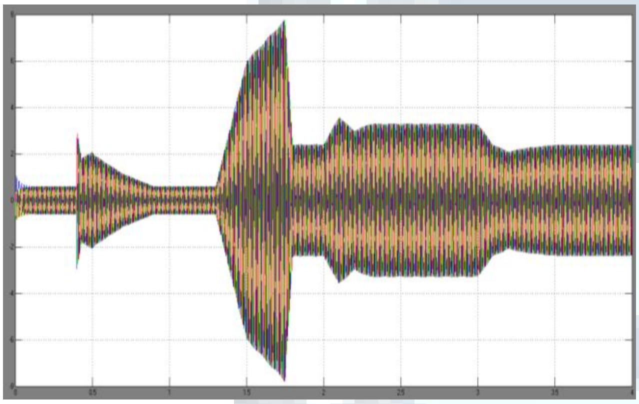
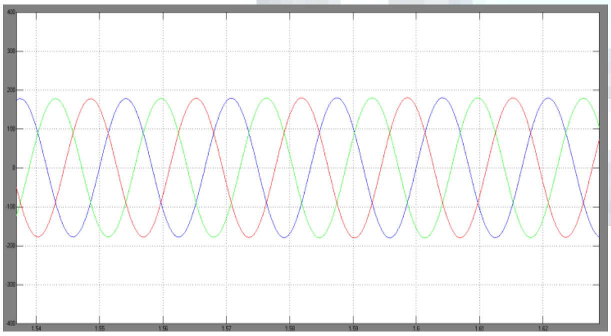


(c)
Fig.11. Generator active and Re-active power.

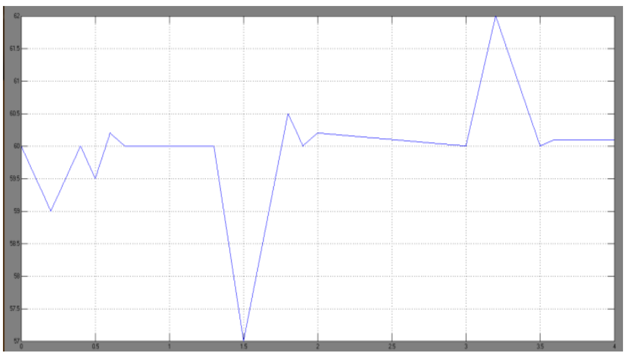
***Case ii:** The proposed micro grid with pulse load variation with DC support.*



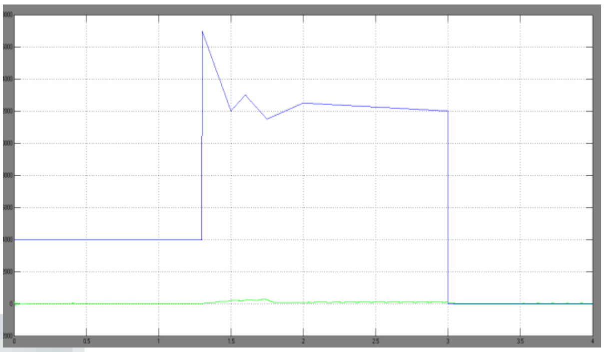
12.(a) Ac side current with Ac pulse load influence.



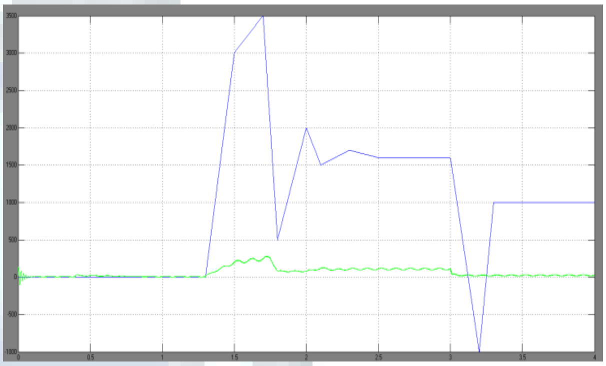
12.(b) Microgrid AC side voltage and current response with DC support.



13(a) Ac Side frequency response.



13(b) Generator side output active and reactive power.



13(c) Ac side active and reactive power with pulse load.

VI. CONCLUSION

A coordination power flow control method of Multi power electronic devices is proposed for a hybrid AC-DC Micro grid operated in islanding model. The micro grid has a PV farm and a synchronous generator supply energy to its DC and AC side. Battery banks are connected to the DC bus through Bi-directional DC-DC converter. The AC side voltage Amplitude and frequency are regulated by the bi-directional AC-DC inverter. The system topology together with the control algorithm are tested with the influence of pulse load. The Simulation results show that the proposed micro grid with the Control algorithm can greatly increase the system efficiency, Stability and robustness.

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