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ARTIFICIAL NEURAL NETWORK BASED EFFICIENT POWER TRANSFERS BETWEEN HYBRID AC/DC MICRO-GRID

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***Abstract*— Hybrid ac/dc micro-grid is a concept of decoupling dc sources with dc loads and ac sources with ac loads, while power is exchanged between both sides using a bidirectional converter / inverter. This necessitates a supervisory control system to split power between its different resources, which has sparked attention on the development of power management systems (PMSs). In this paper, a robust optimal PMS (ROPMS) is developed for a hybrid ac/dc micro-grid, where the power flow in the micro-grid is supervised based on solving an optimization problem by using Artificial Neural Network (ANN). The artificial neural network control is used for dc/ac conversion with PWM control to improve the power quality. A small hybrid microgrid has been modeled and simulated using the simulink in the MATLAB. Satisfying demanded power with maximum utilization of renewable resources, minimum usage of fuel-based generator, extending batteries lifetime, and limited utilization of the main power converter between the ac and dc micro-grids are important factors that are considered in this approach. Uncertainties in the resources output power and generation forecast errors, along with static and dynamic constraints of the resources, are taken into account. Furthermore, since uncertainties in the resources output power may result in fluctuations in the dc bus voltage, a two-level controller is used to regulate charge/discharge power of the battery banks. Effectiveness of the proposed supervisory system is evaluated through extensive simulation runs based on dynamical models of the power resources.**

Index Terms — **ROPMS, ANN, PWM, micro-grids.**

I. INTRODUCTION

Nowadays, because of high penetration levels of renewable energy resources, the paradigms of micro grids (MGs) and distribution generation (DG) are gaining vital role in power and distribution systems. MGs are categorized as ac MGs, dc MGs, and hybrid ac–dc MGs. Since a considerable portion of renewable energy resources, such as wind turbines, photo voltaic (PV), fuel cells and energy storage systems, and many modern loads such as communication technology facilities, data centers, and motor drives is dc-type, dynamics and controls of rectifiers and dc MGs are gaining high interest. However in dc grids, many generation units such as wind turbines must be interfaced to the utility grid via electronically interfaced (EI) rectifiers. In addition, several modern ac loads are coupled to ac grids through back-to-back rectifier-inverter to provide variable frequency operation.

Based on predictions given in, the resistive load share will be significantly reduced whereas the EI loads share will increase to 60-80% of the total load by 2015.The conventional control topologies for three-phase converters are the voltage-oriented vector control and direct-power control. The dq components of the current vector are regulated by a controller generating appropriate values for the converter dq voltage components.

A phase locked-loop (PLL) is required to transform current and voltage variables from the abc frame to the dq frame. It is also feasible to implement the controller in the stationary frame or the abc frame using a proportional-resonant (PR) controller. An alternative control strategy is to use direct power control in which voltage components are adjusted based on active and reactive power errors. None of these methods, however, can directly control the frequency and the load angle. One of the major challenges facing future power systems is significant reduction in grid equivalent rotational inertia due to the expected high penetration level of EI units, which in turn may lead to frequency-stability degradation. To overcome this difficulty, controlling VSCs as virtual synchronous machines is proposed for power system frequency stabilization by embedding a short-term energy storage to the VSC facilitating power flow to and from to the energy storage device proportional to the variation in grid frequency, the idea of synchronous inverters was addressed to emulate the mechanical behaviour of a synchronous generator (SG) in inverters. However, the dc-link is considered as an ideal one with infinite energy and the dynamics of dc-link voltage is not considered.

Moreover, its application to rectifiers has not been addressed. In, methods to emulate virtual inertia in VSCs interfacing wind turbines and HVDC systems are presented; however, the embedded inertia does not emulate the behavior of an SG. The analogy between voltage-source inverters and SG-based MGs has also been addressed. The aforementioned survey indicates the interest in developing new and improved control algorithms for VSCs to emulate the dynamic behavior of SGs. Beside overall low inertia, future power systems and MGs will suffer from interactions between fast responding

VSCs and slower SMs which may contribute to angle, frequency, and voltage instability. With the expected high penetration level of power converters in future power grids, a power system may face severe difficulty in terms of frequency regulation because of lack of rotational inertia in converter-interfaced generators.

Another challenge is that frequency dynamics are not known in the conventional control techniques of VSCs (e.g., voltage-oriented control and direct-power control) which makes it difficult to analyze the angle and frequency stability of a system containing several EI units and conventional synchronous machines (SMs) and line-start motors. Therefore, the development of VSCs with well-defined angle, frequency, and dc-link voltage characteristics (similar to SMs with extension to dc-link dynamics) are of high interest for future smart power systems with a high penetration of VSCs. Moreover, a general control scheme which is suitable for both rectification and inversion modes without reconfiguration is very attractive in power system applications since bidirectional VSCs can work generative and motoring modes similar to SMs.

Another concern related to conventional controls is the existence of a PLL. In these controllers, a PLL is required to extract the grid angle and frequency to transform current and voltage variables from abc to dq frame and vice versa and to synchronize the VSC with the grid. However, it is well understood that PLL dynamics can affect VSC stability, particularly in weak grids. Therefore, there is a persistent need to eliminate the PLL after initial synchronization.

A power synchronization technique is proposed to remove the PLL in the steady state by a simple power loop with an integrator to adjust the VSC's angle based on real power error; in fact, this loop acts as a virtual PLL. However, this method does not exactly mimic the behavior of SMs. The concept of self-synchronization using linear controllers is discussed. Novel control strategies using nonlinear synchronizing power are addressed in to provide self-synchronization ability and large-signal stability for VSCs in MGs and very weak grid applications.

Instabilities due to dc-link dynamics are one of major sources of instabilities in VSCs. Most of previous works on virtual SGs and/or self-synchronization of VSCs consider the dc link as an ideal battery with infinite energy. However, it is obvious that this is not the case and, in most transient scenarios, dc-link voltage varies; also, its energy and power are limited. Moreover, if dc-link voltage dynamics are slow and the voltage passes some thresholds for a relatively long time, under or over-modulation and, consequently, voltage instability is expected. To improve dc-link voltage stability, fast response short-term energy storage can be installed in distributed generation (DG) units.

II. ANN CONTROL FOR MICROGRID

To improve the performance of the gate control circuit for PWM inverter and DVR control in PV/Fuel cell based micro-grid, a multilayer back propagation type artificial neural network controller is used. The back propagation algorithm is used to train the network. The Gradient decent method is used to find the local minimum of a given function. The GD method is the first order optimization algorithm and it is robust when it start far of the final minimum.

The Levenberg Marquardt back propagation algorithm is the second order optimization and it is more robust & finds a solution even if it does begin far from the final optimum. The Levenberg Marquardt algorithm is interpolates between the Gauss Newton algorithm and gradient decent method and it is best comparing to Gauss Newton and gradient decent method.

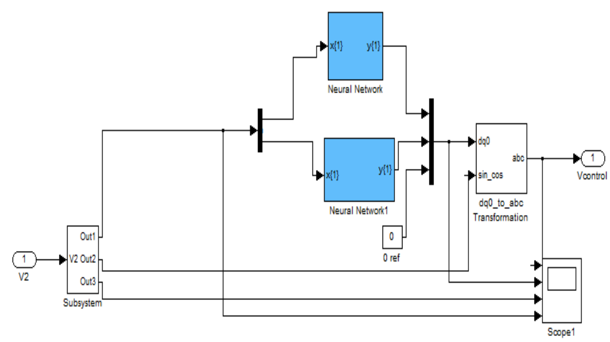

Fig. 2.1 ANN control circuit for Inverter control

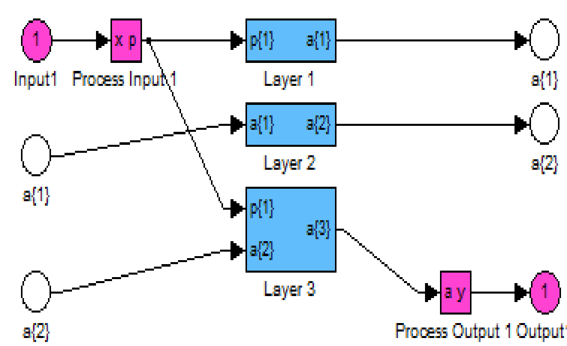

Fig. 2.2 Multilayer ANN network for control circuit

In fig-2.1 shown the artificial neural network control simulation circuit in MATLAB simulation for DVR control and PWM inverter control in the microgrid with Levenberg Marquardt back propagation algorithm.

All the input is used to train the ANN from conventional controller. As shown Fig-2.2 the artificial neural network contain the three layer composed of two input layers and one output layer. Here Input1 and a(1) are the input layers and a(2) are the output layer of the network. Each input layer have the input with weights W_{11} with adder function to compute the weighted sum and input of the layer. It is also containing a linear transfer function as activation function and bias **b**.

Output= activation function (weighted sum of inputs + bias)

The Output layer have the process input from input1 and a (2) with the delay and input weight as shown the Fig-2.3.
The output is given by:

$$\text{net sum}=(p(1)w\{3,1\})+(a(2)W\{3,2\})$$
$$\text{Output } (a\,\{3\})=AF(\text{net sum} + b\{3\})$$

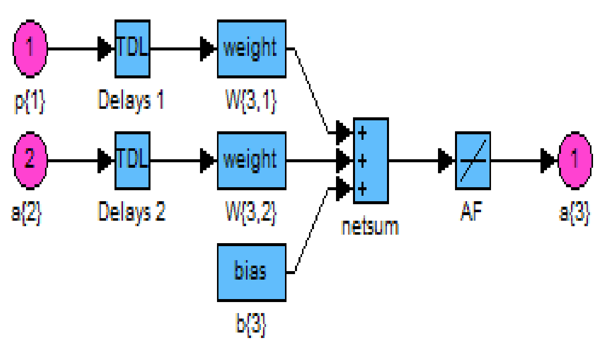

Fig. 2.3. Output Layer for ANN

The input of the artificial neural network with error, so the error signals are not fed directly to the artificial neural network. first the error signals from input and phase signal from PLL is converted from abc to dqo.

The abc to dqo transformation will done on three phase signal and it computes the direct axis V_d ,quadratic axis V_q and zero sequence V_o quantifies two axis rotatively reference frame.

III. OPERATING PRINCIPLE

The proposed circuit deals with the full bridge coupled through a transformer to full bridge rectifier with the PWM pulses applied to them. This system gives a better conversion efficiency is to be proved in simulation done in MATLAB 7.10 The proposed PMS is designed to maximize the profit of sold power. A PV/battery micro-grid is considered, and an optimization-based PMS is proposed mainly to minimize the energy bill of the owner of the system. An ANN optimization-based PMS for the hybrid ac/dc micro-grid is proposed, in order to achieve a robust, efficient, and optimal power flow in the hybrid micro-grid. Our goal is to satisfy demanded power and control the power exchange between the micro-grids, while trying to achieve maximum utilization of renewable resources, minimum usage of fuel-based generator, extending batteries lifetime, and limited utilization of the main power converter between the ac and dc micro-grids. We do optimization process earlier (using less number of feature dimensions) A wireless based trigger is enabled to initiate the power transfer and hence it is not affected by any physical damage of signal transmission lines.

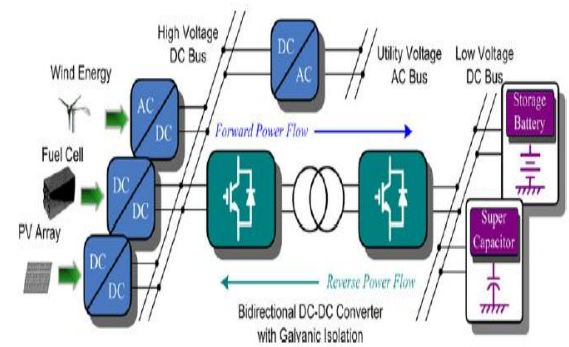

Fig. 3.1 Bidirectional DC-DC Converter with galvanic isolation

A) AC Micro-Grid

In AC micro-grid, we use wind turbines and diesel engine to produce the power in the form Alternating Current. PMSG (Permanent Magnet Synchronous Generator) is used to get the mechanical output from the wind turbines and to convert it to electrical power. The AC output which is obtained from PMSG is converted into Direct Current by using Rectifier. Since the rectified output voltage will be less in general, we use DC/DC converter in order to increase the voltage efficiency. The boosted DC voltage is then sending to Static inverter to get converted into AC voltage and it is used for commercial purposes by means of AC load. The excessive power which is obtained from the DC/DC converter other than the power used for commercial purpose is stored in the Battery bank for future use.

When the mechanical output of wind turbines get reduced because of some natural reasons, diesel generator is used. This also works on the same principle of wind turbine. The output of diesel engine is also stored in battery banks. The output voltage from the battery bank is boosted up using DC/DC converter. The amplified voltage from the DC/DC converter is sent to the static inverter which converts the DC output to AC load.

B) DC Micro-Grid

The output from the photovoltaic array is boosted up by using DC/DC converter which is regulated by load side converter and it is used by DC load for commercial purposes. The stored DC voltage in battery bank is used when the output from the photovoltaic array is less

The present system consists of ac and dc grid systems. Both equipped with a bidirectional ac to dc converter. This enables the loads to bet power supply irrespective of shortage in power, with some constraints.

C) Wind Turbine

The WT presents a rated power of 1.5 kW. It presents a two blade turbine coupled to a three-phase permanent magnet synchronous generator (PMSG). This WT is represented by a model with the following subsystems: turbine and generation system. The turbine model expresses the mechanical power extracted from the wind, which is a function of the wind speed and the blade tip speed ratio, as defined by the actuator disk theory. The generation system is composed of a three-phase PMSG, ac–dc converter, and dc–dc converter, which are represented by models included in SimPowerSystems. The electrical and mechanical parts of the PMSG are represented by a secondorder state-space model. The ac–dc and dc–dc converters are modeled by average-value equivalent models. The dc–dc power converter, which connects the WT to the hybrid system dc bus, is controlled by a torque reference-based maximum power point tracking (MPPT) control in order to extract the maximum available power from the WT. This MPPT control maintains the operating point of the WT on its maximum power coefficient for any wind speeds in the below-rated wind speed region, modifying the duty cycle of the WT dc–dc converter, which produces a variation of its rotational speed. Furthermore, the WT generation system incorporates a braking resistor at the dc bus, in which the power excess with above nominal winds is dissipated to assure WT rated power.

D) PV Panels

The PV system presents nine 0.180-kW PV panels, with a total rating of 1.6kW.Asingle-diodemodel, which is composed of a current source and a parallel diode (representing the ideal PV cell) with two resistances (series and parallel resistances), is used to represent each PV panel. This model presents suitable accuracy, and the parameters are easy to find in the commercial datasheets, which makes it perfect for the simulation of PV devices with power converters. A dc–dc power converter controlled by a MPPT controller adapts the PV output voltage to the dc bus voltage. The MPPT controller generates the duty cycle of the PV converter to move the PV voltage to the voltage that corresponds to the maximum power point (MPP). In this work, the MPP voltage is defined as proportional to the PV open-circuit voltage. Thus, a fractional open-circuit voltage algorithm is used as MPPT algorithm to generate the duty cycle of the controller due to its simplicity.

E) Batteries

The hybrid system uses a 14.48-kWh lead-acid battery. This type of battery is usually the least expensive storage battery for any application, while still providing good performance and life characteristics. This battery is modeled by a conflict in series with a variable voltage source.

F) *DC–DC Converters*

Each energy source of the hybrid system provides a variable voltage, which depends on the current demand, at different ranges. Therefore, it uses a pulse-width modulated (PWM) dc–dc converter to transfer the output power to the central dc bus. The output voltage of the WT rectifier is higher than the dc bus voltage. Thus, the WT plus rectifier system is connected to the dc bus by using a buck-type unidirectional converter. The connection of PV, FC, and electrolyzer to the dc bus is performed by using boost-type unidirectional converters. The PV and FC converters transfer power from the source to the dc bus, since both sources terminal voltages are lower than the dc bus voltage. The electrolyzer converter transfers power from the dc bus to the electrolyzer, whose terminal voltage is higher than the dc bus voltage. The battery uses a bidirectional converter, which allows the power flow from the battery to the dc bus (boost-type) and vice versa (buck-type). Each dc–dc converter is modeled by using the two-quadrant chopper model included in Sim Power Systems. In this model, the chopper is represented by a simplified version of the converter containing an average-value equivalent model.

G) Inverter

A three-phase IGBT inverter connects the dc bus of the hybrid system to grid. This inverter is represented by the model developed. In this model, the snubber capacitor is eliminated, so that only the snubber resistance is taken into account. Furthermore, the forward voltages of the IGBTs and diodes are considered null. The inverter is PWM to produce the three-phase 50-Hz sinusoidal voltage. It uses adaptive neural network switching and controls the active and reactive power, as will be shown below.

IV. CLASSICAL ENERGY MANAGEMENT SYSTEM OF THE HYBRID SYSTEM

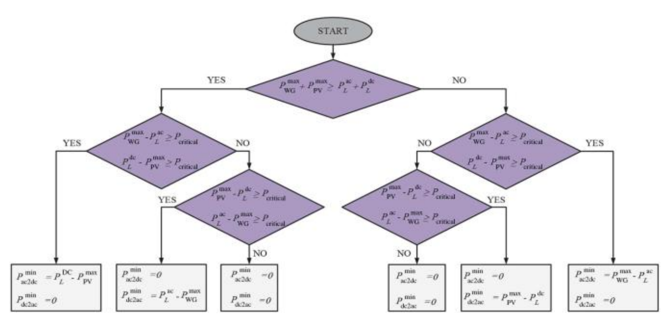

Fig.4.1 Scheme of the supervisory control system based on states

Here, the classical EMS used to test the performance of the proposed Adaptive neural network control system is described. The classical EMS is composed of state-based supervisory control system based on states and inverter control system based on PI controllers. The supervisory control system uses the control scheme shown in Fig. 2 in order to determine the power generated by/stored in the hydrogen and battery, taking into account the power demanded by the grid, the available power, the hydrogen tank level and the battery SOC. The neural network will minimize the error in both d and q coordinates with the help of training algorithm. After minimizing the error signal the dqo convert in abc components again. The control signal will feed to the PWM generator to generate the gate pulses for controlling PV inverter in microgrid.

V. SIMULATION RESULTS

A) Forward Power flow

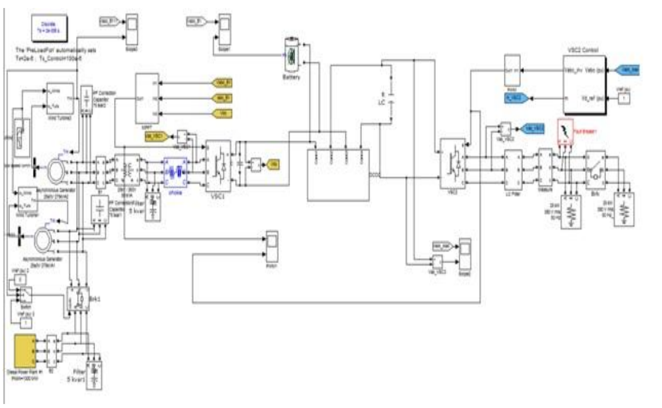

Fig.5.1 State model of wind, diesel in the forward direction

The above Simulink model shows the power generation using wind, diesel in the forward direction. The power generated is converted into DC and the same is stored in the form of DC in a backup battery. The bidirectional DC-DC converter allows the power flow in both the directions. Hence, either AC grid or DC grid would get power based the power demand and the availability.

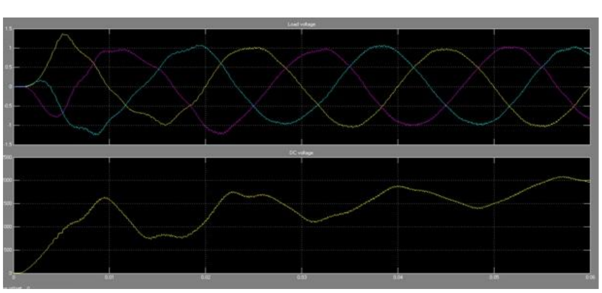

Fig.5.2 Load Voltage Output waveform.

This output shows the three phase voltage at a three phase load supplied from a combined diesel and wind source along with the DC voltage stored in the battery at DC side. The settling of voltage waves to stable values takes at least 0.05 s to give a stable voltage.

B) Reverse Power Flow

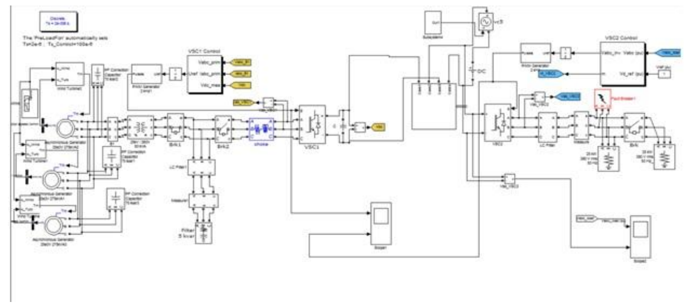

Fig. 5.3 State model of Reverse power flow from DC to AC side

The above model shows the reverse power flow from DC to AC side. Where the breakers are programmed to allow only the DC power and blocks the AC power to the load placed at the AC grid side. The power generated from solar panels and already stored in the batteries are transmitted in reverse direction via a bi directional dc-dc converter and hence that is inverted and supplied to the three phase load after a proper LC filter to convert into a pure sine wave.

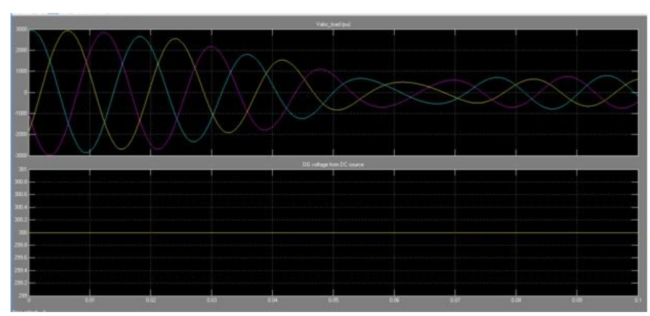

Fig. 5.4 Load voltage at AC side and DC Voltage at DC Grid side Output waveform

This output shows the three phase voltage at a three phase load supplied from DC grid along with the DC voltage stored in the battery at DC side. The settling of voltage waves to stable values takes at least 0.07 s to give a stable voltage. The settling time depends on the controller efficiency. The DC voltage shown in the figure is the summation of the solar panel and the battery voltage.

VI. CONCLUSION

In this paper an isolated hybrid ac/dc micro-grid is proposed to satisfy power demand in both the ac and dc micro-grids. The optimal power flow for the hybrid ac/dc micro-grid is assessed through minimizing a cost function along with some operational constraints. In this project, a two-level control scheme is utilized in order to determine charge/discharge power of the battery banks and regulate the voltage level. Since generation forecast errors may severely affect the obtained optimal solution, a robust formulation is used to treat these uncertainties. Power imbalances caused by uncertainties in the resources output power, can change the voltage level of dc bus in the dc micro-grid, and bus DC in the ac micro-grid. The project may be used as a centralized controller to maintain all the buses included in the grid. Presently the scenario has been explained for few buses. Any further optimizations may be included in this work in order to have robust control over power quality parameters. (presently power quality parameters have not been addressed) The system may be designed as an embedded hardware in order to convert all control algorithms into VLSI based control. Power level may be increased in order to check the robustness of the control algorithms.

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