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Design and Analysis of a 3-Phase Grid Connected Wind and Solar Power Integrated Systems

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ABSTRACT

This paper exhibits a novel vitality dispatching in view of Model Predictive Control (MPC) for off-framework photovoltaic (PV)/wind turbine/ hydrogen/ battery mixture frameworks. The sustainable power sources supply vitality to the cross breed framework and the battery and hydrogen framework are utilized as vitality stockpiling gadgets. The named "hydrogen framework" is made out of power module, electrolyzer and hydrogen stockpiling tank. The MPC produces the reference forces of the power module and electrolyzer to fulfill distinctive destinations: to track the heap control request and to keep the charge levels of the vitality stockpiling gadgets between their objective edges. The displaying of the crossover framework was created in MATLAB-Simulink, considering datasheets of economically accessible segments. To demonstrate the correct operation of the proposed vitality dispatching, a less difficult technique in view of state control was displayed keeping in mind the end goal to analyze and approve the outcomes for long haul recreations of 25 years (expected lifetime of the framework) with an example time of 60 minutes.

KEYWORDS: *Model Predictive Control, PV panels, hydrogen framework, rectifier-inverter.*

I. INTRODUCTION

The present circumstance of the vitality area with a nonstop increment in the vitality request, together with the Greenhouse gas discharges and the weariness of the non-renewable energy source saves have improved the mix of sustainable power hotspots for dispersed era. This mix is designated Hybrid Renewable Energy Systems (HRES) or essentially Hybrid Systems (HS) which are made by at least one sustainable power sources and vitality stockpiling frameworks (ESS). ESS permits adjusting the unregulated power produced by the sustainable sources to a particular requested power. This HS can work in remain solitary or grid associated mode. The right outline of the vitality dispatching for HS is basic for their operation. vitality dispatching methodologies are intended to track the heap control fulfilling auxiliary goals, for example, keeping the charge level of the vitality stockpiling gadgets inside their operational breaking points, limiting the era costs, working the framework at high proficiency, lessening the fuel utilization, and so on. The papers identified with vitality dispatching can be characterized by these targets. Contingent upon the goals to meet by the vitality dispatching there are two sorts of reproductions that can be completed: short term

and long haul reenactments. Here and now reenactments are concentrate on the flow of the sources which create the framework and consider to confront the net power varieties because of the adjustments in stack power or aggravations in the sustainable power sources. The length of this sort of reproductions goes from 200 s to one day. Long haul reenactments are utilized when the primary goal is to demonstrate the correct operation of the framework amid an impressive timeframe (from months to the entire existence of the framework). For this situation, the progression of the vitality sources are disregarded and they focus on different parameters, for example, operation costs, debasement of the sources, level of charge of the capacity gadgets, and so forth. Demonstrate Predictive Control (MPC) has been broadly utilized as a part of the vitality dispatching plan on account of its capacity to manage limitations in a methodical and clear way. The HS was created by wind turbine, PV, electrolyzer and power module. The vitality produced by the sustainable sources (both controlled by Maximum Power Point Tracking e MPPT-calculations) was put away as hydrogen. In the event that the inexhaustible power was higher or lower than the requested power, the electrolyzer or the energy unit worked. Both, the energy unit and the electrolyzer, had a MPC which created their reference current subject to their dynamic compels. The goal of the technique was to take care of the heap demand considering the dynamic restrictions of the vitality sources however it was not appeared if the procedure can keep up the hydrogen level in the tank. Vahidi et al. considered a basic HS for remain solitary applications created by an energy unit associated with a heap by a DC/DC converter. The power device was helped by an ultra-capacitor which was specifically associated with the DC transport. A MPC produced the reference current of the energy unit keeping in mind the end goal to guarantee an ideal conveyance of current request between the two power sources and keep up the oxygen abundance proportion of the energy unit and the ultra-capacitor SOC inside their operational breaking points. The recreations did kept going around 20 s and demonstrated that the HS met the control targets. Kassem et al. exhibited a framework formed by wind turbine and synchronous generator driven by a diesel motor for remains solitary applications. The synchronous generator was specifically associated with the three-stage transport and the breeze turbine was associated with it by methods for an uncontrolled rectifier-inverter (AC-DC-AC). The MPC controlled the diesel engine fuel stream rate and the synchronous generator excitation voltage for directing the heap transport voltage and recurrence. The recreations showed the capacity of the controller to remunerate both the breeze control motions and load unsettling influences. Another case of MPC for HS was introduced in Ref. For this situation, the HS was made by power module, electrolyzer and wind turbine, and the MPC objective was to create the water and wind current rates of the energy unit to keep its temperature and oxygen abundance proportion inside their security operation ranges. Be that as it may, a few gadgets and outline, e.g. hydrogen stockpiling, control administration and inverters, were not thought about. Unmistakably the utilization of MPC has been engaged in vitality dispatching with here and now destinations as indicated by the past arrangement. There is an absence of works which propose vitality dispatching in view of MPC with long haul destinations.

II. Off-grid HS under study

The HS under examination is situated in Algeciras (Spain), and it displays the setup appeared in Fig.1. The new vitality dispatching created in this work is approved for this HS. In this HS, the principle vitality sources are the breeze turbine and PV boards (sustainable sources), whose operation is helped by the battery and hydrogen framework (created by power module, hydrogen tank and electrolyzer) filling in as reinforcement and capacity frameworks. In the hydrogen framework, the power device is provided by the hydrogen gave by the tank, which is filled by the electrolyzer. The vitality that streams among the vitality sources is controlled by DC/DC converters which interface them to a typical DC transport. In this HS, when the sustainable power source is higher than the vitality requested by the heap, this vitality abundance can be put away as power in the battery or as hydrogen in the tank (created by the electrolyzer). Then again, when the sustainable power source is lower than the requested vitality, this vitality deficiency can be provided by the battery as well as energy unit. The measuring of the HS was done utilizing Simulink Design Optimization of MATLAB, taking as fundamental introduce that the energy component must have the capacity to give energy to one year without interference. This introduce brings about the HS over sizing, which must be considered since

the overabundance of produced control include that the vitality dispatching must be outlined with a specific end goal to keep away from cheats in the ESSs.

III. Modeling of System Components

3.1. PV panels A single-diode demonstrates was spoken to the conduct of the PV boards. The components which create this model are a present source with a diode in parallel which models a perfect PV cell together with an arrangement and a parallel resistance. The utilization of this model is exceptionally normal in various works. Besides, it facilitates discovering its parameters in the business datasheet. As indicated by this model, the yield current of the PV board is:

$$I_{pv} = I_{ph} - I_{sat}\left(e^{q(V_{pv}+I_{pv}R_s)/(NkT_{pv})}\right) - (V_{pv} + I_{pv}R_s)/R_p \quad (1)$$

$$I_{ph} = I_{ph0}(1 + K_0(T - 300)) \quad (2)$$

$$I_{sat} = K_1 T^3 e^{\left(-\frac{qV_g}{kT}\right)} \quad (3)$$

3.2. Wind turbine The chose wind turbine utilizes a turbine of two edges with settled pitch edge and coupled to a three-stage synchronous generator with lasting magnets. The model of the breeze turbine depends on its consistent state control qualities. The turbine yield control is given by the accompanying condition:

$$P_{turb} = \frac{\rho}{2}\pi R^2 v_t^3 C_P(\lambda) \quad (4)$$

The output of this model is the mechanical torque of the wind turbine which depends on the turbine output power and speed:

$$T_a = \frac{P_{turb}}{\omega_t} \quad (5)$$

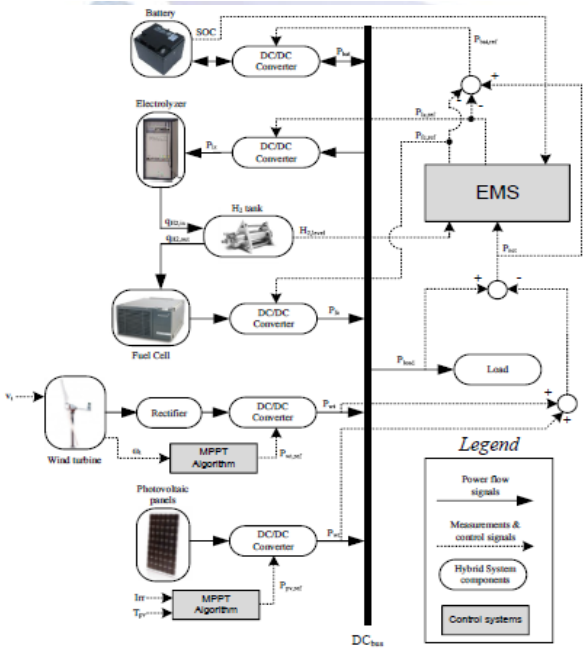

Fig.1. Off-grid HS under study.

The electrical power arrangement of this model is made by a three-stage synchronous generator with lasting magnets, an inverter and a DC/DC converter, every one of them demonstrated as average value identical models in SimPowerSystems. So also to the PV boards, the breeze turbine era framework is associated with the DC transport utilizing a DC/DC converter controlled by a MPPT calculation in view of torque reference. For this situation, the MPPT calculation makes the breeze turbine to work on its most extreme CP for any breeze speeds in the beneath appraised wind speed district by controlling the obligation cycle of the DC/DC converter (the variety of the obligation cycle delivers a variety of its rotational speed). A PI controller thinks about the reference torque (created by a look-into table) to the present torque keeping in mind the end goal to produce the obligation cycle of the DC/DC converter.

Table 1
HS components.

Parameter	Value	Component
Photovoltaic array power	1.62 kW	9 × EOPLLY 125M-72 180 W
Wind turbine power	1.50 kW	1 × Bornay 1500
Battery capacity	8.91 kWh	6 × BAE SECURA PVS Solar 660 (in series)
Fuel cell power	1.20 kW	1 × Heliocentris Nexa 1200
Electrolyzer	0.48 kW	1 × Hydrogen Generator HG 60

3.3. Hydrogen system

3.3.1. Fuel cell Proton Exchange Membrane (PEM) fuel cells, because of its productivity and great dynamic conduct, meet truly all around appropriated era requests. The chose model of PEM energy unit is an improved variant of the model displayed in Ref. what's more, whose legitimacy was shown in Ref. This model has likewise been broadly used to assess vitality administration systems for half breed vehicles. As indicated by this model, the power module yield voltage Vfc is given by:

$$V_{fc} = N_{cell} \cdot (E_{cell} - (V_{act} + V_{oh} + V_{conc})) \quad (6)$$

$$E_{cell} = E^0_{cell} - k_e \cdot (T - T_0) - \frac{R \cdot T}{2 \cdot F} \ln\left(\frac{p_{H_2O}}{p^{0.5}_{O_2} \cdot p_{H_2}}\right) \quad (7)$$

3.3.2. Electrolyzer The model of the electrolyzer is formed by a resistance. The hydrogen delivered by the electrolyzer relies upon the current in this resistance and it is ascertained utilizing the Faraday's law which is given by

$$\eta_{H_2} = \frac{\eta_F \eta_{lz} i_{lz}}{2F} \quad (8)$$

3.4. Battery The utilization of batteries as vitality stockpiling gadgets for off-matrix control supplies is generally broadened. Lead-corrosive batteries introduce a decent execution for this sort of

utilizations and its low cost in contrast with whatever is left of battery advancements was determinant for choosing them for this work. The battery display was taken from the SimPowerSystems tool kit of Simulink which relates to the model introduced in Ref. This model is made by a variable voltage source and an arrangement resistor. The variable voltage is figured utilizing the accompanying articulation:

$$V_{bat} = E^0_{bat} - K_b \cdot \frac{Q}{Q - i_{bat}t} i_{bat}t - R_{bat} i_{bat} + A_{bat} \exp(-B_{bat} \cdot i_{bat}t) - K_b \cdot \frac{Q}{Q - i_{bat}t} i^*_{bat}$$

3.5. DC/DC converters At last, unique PWM-based DC/DC converters, abridged in Table 2, are utilized to associate the diverse vitality sources to the DC transport. These converters permit controlling the vitality stream between the sources adjusting their variable voltages to the consistent DC transport voltage. Normal esteem proportional models (created by current and voltage sources) speak to these converters in this work. This sort of model recreates the dynamic of the converters for substantial example times.

IV. Energy Dispatching

4.1. Energy dispatching based on MPC The vitality dispatching in view of a MPC plot creates the energy of the hydrogen system (PH2), which can be certain or negative in the event that it is the power module or the electrolyzer which works. Fig. 2 demonstrates the general plan of the proposed control procedure.

Table 2
Summary of the HS DC/DC converters.

Power source	Converter	Energy flow (From → To)
PV	Unidirectional – Boost	(PV → DC bus)
WT	Unidirectional – Buck	(WT → DC bus)
Battery	Bidirectional	(Battery → DC bus) – Boost (DC bus → Battery) – Buck
FC	Unidirectional – Boost	(FC → DC bus)
Electrolyzer	Unidirectional – Boost	(DC bus → Electrolyzer)

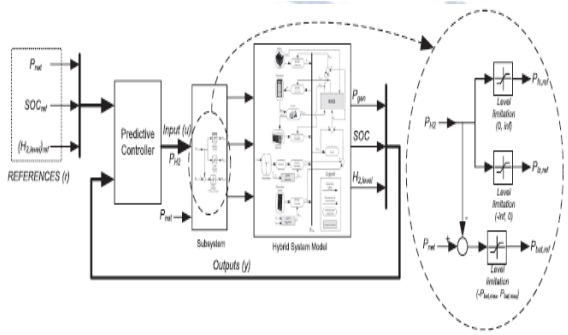

Fig.2. Overall scheme of the energy dispatching based on MPC.

Table 3
Summary of the controller parameters.

Controller parameters		
Control interval (h)	1	
Prediction horizon (intervals)	3	
Control horizon (intervals)	2	
Output constrains	**Type**	**Range**
Load power generated (kW)	Level limitation	[-3000,1800]
Battery SOC (%)	Level limitation	[20,95]
SC SOC (%)	Level limitation	[20,95]
Input constrains	**Type**	**Range**
Hydrogen power (W)	Level limitation	[-480,1200]
Reference values		
Load power generated (kW)		P_{net}
Battery SOC (%)		60
SC SOC (%)		60

4.2. Energy dispatching based on state control This vitality dispatching utilizes a straightforward state-machine control to determinate the energy of the battery, energy component and electrolyzer relying upon the net power, battery SOC and hydrogen level. The flowchart displayed in Fig.3 demo-nstrates the distinctive operation states. Three levels of battery SOC and hydrogen in the tank have been viewed as (high, H; ordinary, N; and low, L). The progressions among these levels are performed by utilizing the hysteresis cycles demonstrated Fig. 3. Both vitality dispatching have changes to separate the sustainable power sources and to maintain a strategic distance from cheats of the capacity units.

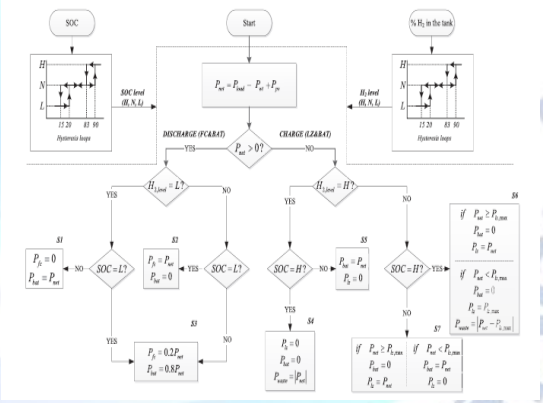

Fig.3. Flowchart of the energy dispatching based on state control.

V. MATLAB Design & Results

Existing Model:

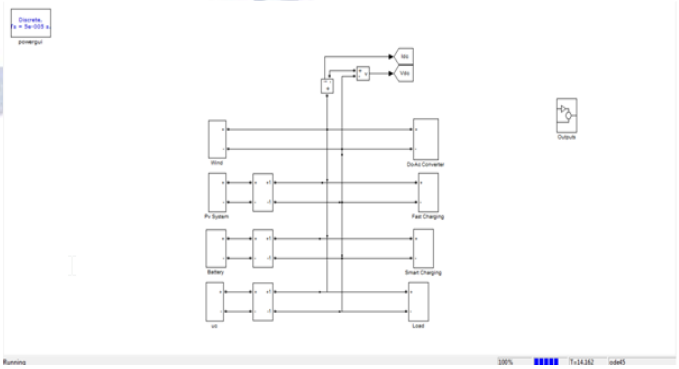

Fig 4.1 Existing model

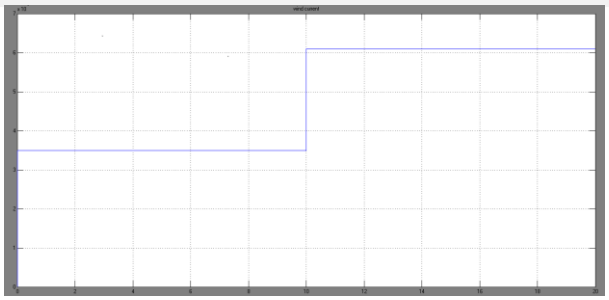

Fig 4.2 wind current

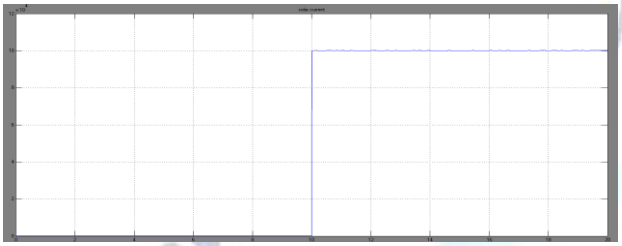

Fig 4.3 Solar current

Proposed Model: In the proposed model we are using a 3-phase grid is connected to wind and solar system as a power integration system.

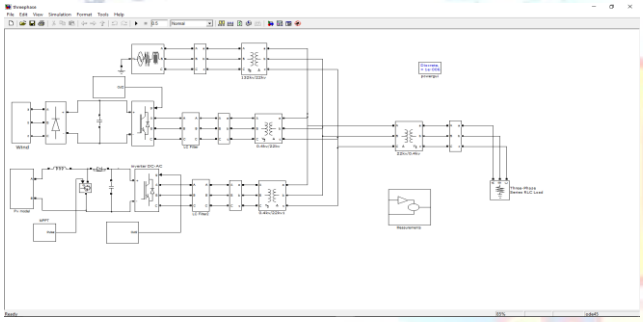

Fig 4.4 Proposed model.

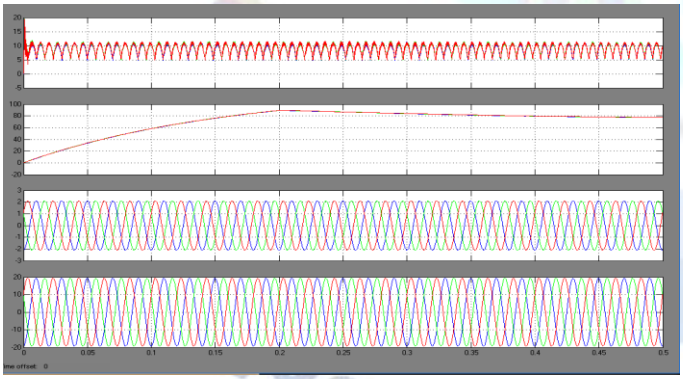

Fig 5.2 Shows: Wind current (iabc), Solar current (ipvabc), 3-phase Grid (IEabc)

VI. Conclusions

The fundamental commitment of this work has been to display and assess a vitality dispatching in light of MPC for an off-network HS incorporating wind turbine, PV boards, hydrogen framework and battery. In this HS, the sustainable power sources produce the greatest accessible power, though the vitality dispatching is in charge of controlling the operation of battery and hydrogen framework. In this vitality dispatching, the prescient controller decides the energy of the hydrogen framework (positive for the energy component and negative for the electrolyzer) considering the power produced by the controllable power sources, the battery SOC, and the hydrogen level. The battery control is gotten from the distinction between the net power (stack control short PV power and wind turbine control) and the hydrogen framework. The vitality dispatching in view of MPC was approved by examination with an ED in light of state control. The reproduction comes about, got for the assessed lifetime of the HS (25 years), exhibited that the vitality dispatching in light of MPC accomplished a higher worldwide productivity of the HS, guaranteeing the off-framework stack support and keeping the battery SOC and hydrogen level between the coveted working points of confinement.

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