DESIGNING OF MODEL PREDICTIVE CONTROL ALGORITHM FOR ACTIVE AND REACTIVE POWER CONTROL OF A MICROGRID

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Abstract- *Microgrid development is a viable solution for integrating rapidly expanding renewable energy sources. However, the stochastic nature of renewable energies and changeable power demand has caused a slew of issues, including unstable voltage/frequency, difficult power management, and grid interaction. Predictive control has recently shown tremendous potential in microgrid applications due to its fast transient response and flexibility to suit various restrictions. This work examines model predictive control (MPC) in individual and interconnected microgrids, including converter- and grid-level control techniques applied to three layers of the hierarchical control architecture. MPC research is just getting started in microgrids, but it's already proving to be a viable alternative to traditional approaches for voltage regulation, frequency control, power flow management, and economic operation optimization. In addition, some of the most significant patterns in MPC development have been identified and addressed as future prospects.*

Key Words: Grid-Connected PV System, solar panel, inverter, renewable energy, MATLAB/SIMULINK, Model predictive control, microgrid, primary control, secondary control.

1. INTRODUCTION

Renewable energy systems (RESs), such as photovoltaic systems (PVs) and wind turbine systems (WTs), have advanced fast in recent decades as a result of ecological, social, economic, and political pressures and interests [1-3]. Microgrids have emerged as a promising way to interconnect RESs, energy storage systems (ESSs), and loads through various power electronics interfaces to better integrate distributed generation (DG) into the utility grid [4-8].

A microgrid can function in grid-tied mode as a controllable single unit, or in islanded mode as a self-sufficient autonomous system, depending on how it interacts with the utility grid. Microgrids are divided into three categories based on the most prevalent buses: dc, ac, and hybrid.

The setup of converter-interfaced microgrids with dispersed RESs and ESSs is shown in Figure 1. A microgrid can be connected to other microgrids via various converters, as depicted. It can also be connected to the utility grid via a shared coupling point (PCC). The diagram of interconnected microgrids is shown in Fig. It demonstrates how microgrids can be networked in a radial or mesh architecture, with power flow managed by a distribution network operator (DNO). PV, WT, ESS, electric vehicle (EV), resident, and industrial systems can all be accommodated in each microgrid. Model Predictive Control (MPC) is a control methodology that has been successfully utilised in the industry to address complicated control problems, and it is actively being investigated and embraced in the research community. This study examines the applicability of MPC to microgrids in terms of their primary functions. outlining the design methodology as well as the most recent developments Finally, the problems and future prospects of MPC and its microgrid applications are explained and summarised. The evolution of the smart grid to a more structured system based on microgrids and storage systems that cooperate and self-organize appears to be a key to transforming our existing energy system into a more sustainable one. Through evolving adaptability (ancillary service) markets and novel grid management concepts, a microgrid-based smart grid structure would not only allow greater coordination of emerging distributed components in the wholesale market, and it could also be used as a part of distribution and transmission system management. The ability of microgrids to operate in grid-connected/islanded mode, as well as the mobility given by energy storage systems in microgrids, look to be important solutions to the challenge created by future transmission and distribution networks. In the future power system, microgrids could strengthen dependability, cut emissions, and extend energy sources. They may greatly enhance grid security and stability. Several microgrid facilities can also recover and use heat from their DG systems, a method described as combined heat and electricity generation. Cooling generation can also be used as a power-to-X or flexibility tool. Another level of flexibility is given by directly connecting microgrids into networks of microgrids. Microgrids can also improve the energy system's resilience, security, and knowledge in order to progress toward an energy system that can support a substantial share of variable renewables. Figure depicts the many operations of microgrids in a structured smart grid, as well as their relationships with the various stakeholders in the electric market.

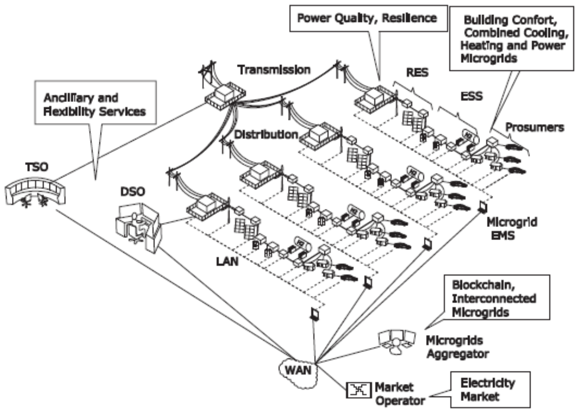


Fig -1: Overview of the main functionalities of microgrids

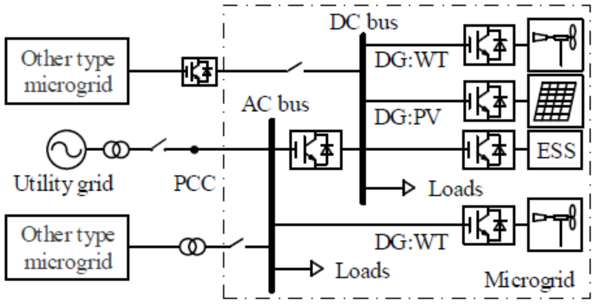


Fig -2: Configuration of converter-interfaced microgrids

1.1 A Review of MPC-Based Control Methods for Microgrid Applications

The microgrid control system must deal with a variety of issues over a variety of timelines. The system must be optimised for day-ahead electricity markets, which necessitates 1-hour sample periods. real-time control of power quality and reliability (PQR) issues—quick electrical control of individual phase, frequency, and voltage. Unit commitment, economic dispatch, demand-side optimization, and energy exchanges with the utility grid must all be done in seconds or less; unit commitment, economic dispatch, demand-side optimization, and energy exchanges with the utility grid must all be done in minutes or hours. As a result, in order to establish a comprehensive strategy, an extensive methodology is required. hierarchical control structure that handles these different time scales. These levels are shown in Figure and are explained in depth in [08].

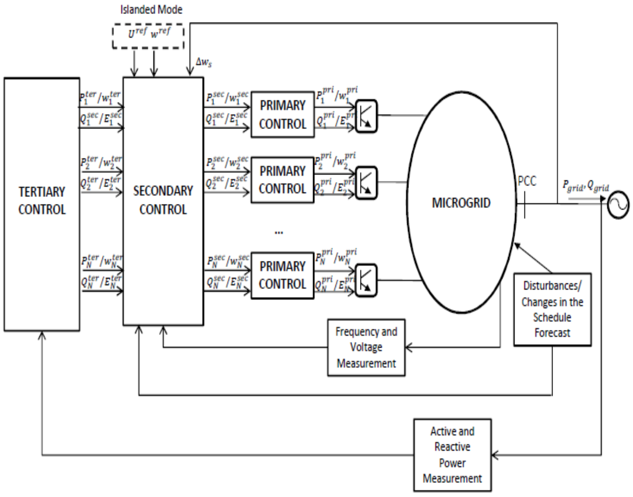


Fig -3: Microgrid control level architecture

1.2 MPC for Power Converters

The FCS and the Continuous Control Set are two basic control techniques used in the field of MPC to control power converters (CCS). The FCS is based on the fact that a power inverter has a limited number of switching states. In order to forecast the behaviour of the converter, the optimization issue is simplified by considering these alternative switching states. The set of permissible switching sequences is enumerated at each sample instant, the appropriate system response is anticipated, the cost function is assessed, and the sequence with the lowest cost is selected [07]. As control actions, the CCS technique sends continuous-time signals. which are delivered to a modulator, and the optimization issue is solved analytically in the unconstrained case by setting the derivative of the cost function to zero. Its key benefit is the ability to use larger control horizons because an analytical answer is available. The complicated topologies of power inverters, however, make it challenging for this methodology to develop an effective model.

1.3 MPC for Voltage and Frequency Regulation

In a coordinate mode, microgrids are made up of several parallel-connected distributed generators, storage devices, or controllable loads that can operate in both grid-connected and islanded modes. In islanded mode, system stability and power quality must be maintained among the various parallel interconnected devices. Deficit balances in active and reactive power between the different components of microgrids can lead to poor power quality indexes due to a variety of factors, including the effects of feeder impedance mismatch and the varying ratings of dispersed units. Devices connected to the same microgrid AC/DC bus may be harmed. In connected mode, imbalances in active/reactive power might disrupt the tertiary control schedule carried out with the main grid.

2. Basic Principle of Model Predictive Control

Actually, MPC refers to a group of control approaches that take full advantage of the system model under specific restrictions to provide control signals or directives by minimising predetermined cost functions or objective targets [10]. When it comes to MPC in microgrids, In terms of converter level and grid level, it can appear to be different. In general, the former generates switching signals to operate power converters, while the latter determines DG and controlled load dispatching directives. However, based on the common MPC architecture, these two layers have a similar control structure and design approach. On this point, it is possible to state that there is none.

2.1 Converter-level MPC

MPC at the converter level has been actively developed over the last few years. The most commonly utilised variants of CCS-MPC are generalised predictive control (GPC) and explicit MPC, because a consistent switching frequency is generated. GPC was employed with the LCL filter in both Refs. [10] and [11] to solve harmonic difficulties. [07] . In an explicit MPC for dc-dc converters, a neutral network core was inserted to develop the input-output model. Those who consider control time sequence in FCS-MPC are an important emerging branch. A deadbeat methodology was used in Ref. [08] to regulate currents throughout one control period, allowing for improved control of the control time sequence. Furthermore, in Ref. [09], fixed switching frequency and improved steady-state performance were simultaneously obtained by improving the FCS-MPC.

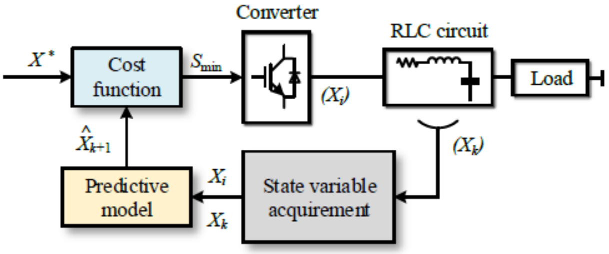


Fig -4: Diagram of converter-level MPC

2.2 MPC for Grid Level

The grid-level MPC will have the same predictive model, cost function, and solving technique as the converter-level MPC. Grid-level MPC, on the other hand, tries to control standard operating statuses (e.g. ESS capacity, power flows within a microgrid or among networked microgrids). Grid-level MPC is an optimization procedure that could be used to improve the performance of constrained systems that have lots of responsibilities. The general diagram of grid-level MPC is shown in Fig. 5. The predictive model, as illustrated, is based on system states and probable forecasts. It creates an expression for predicting future states based on present and previous states. More specifically, the predictive model's forecasts/predictions can be various state variables on a time-interval basis, such as load demands, electricity pricing, PV/WT generation, and so on.

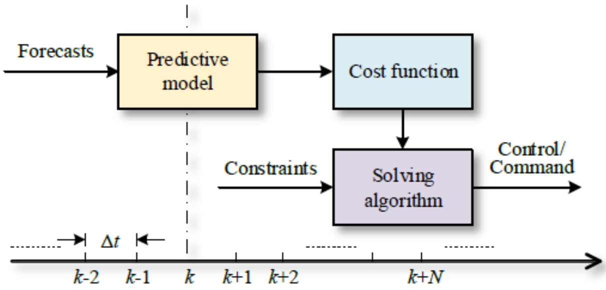


Fig 5 : Diagram of grid-level MPC

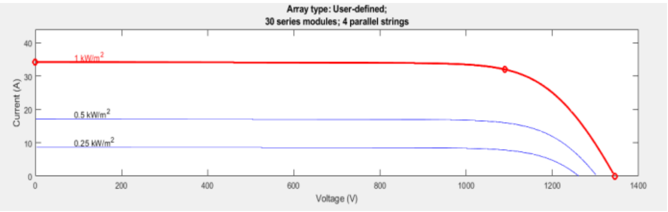
3. Designing of MICROGRID BASED ON MPC CONTOL

The proposed controller for the PV system is modeled in MATLAB-Simulink. The I-V and P-V characteristics of the PV system for different irradiance levels are shown in figure. The SUNPOWER SPR-305- WHT is used as PV module type. The PV module characteristics under standard test condition (STC: solar irradiance = 1 kW/m2, cell temperature = 25 deg. C) are:

Open circuit voltage (Voc) = 64.2 V
Short-circuit current (Isc) = 5.96 A

3.1 Simulation diagram and results

3.1.1 PV array I-V characteristic



3.1.2 PV array P-V characteristic

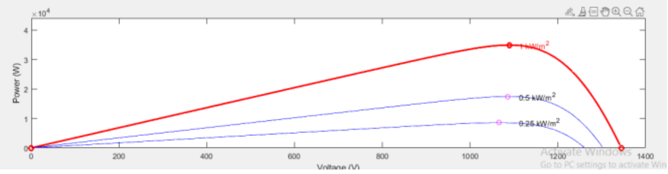
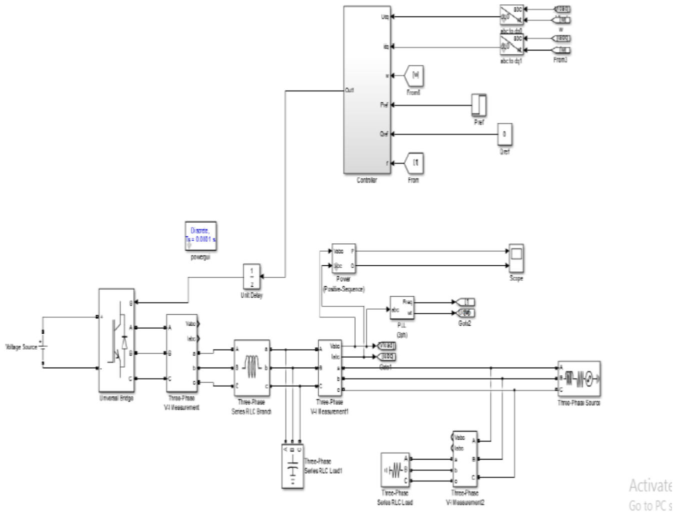
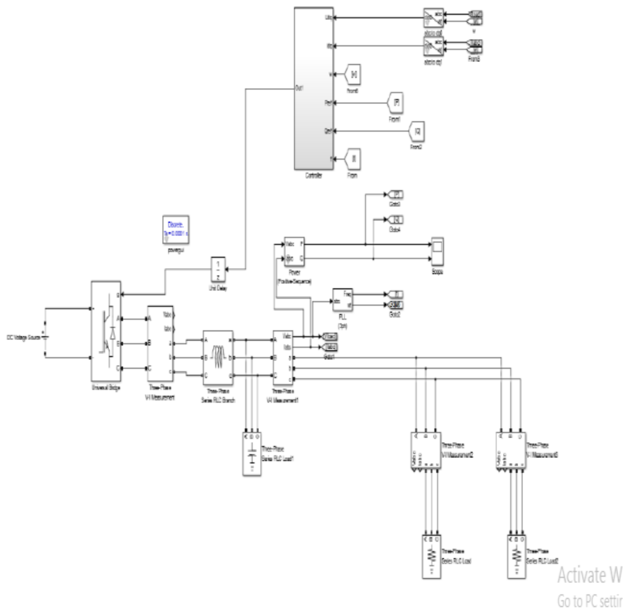


Table -3 : Output voltage of the converter with change in insolation

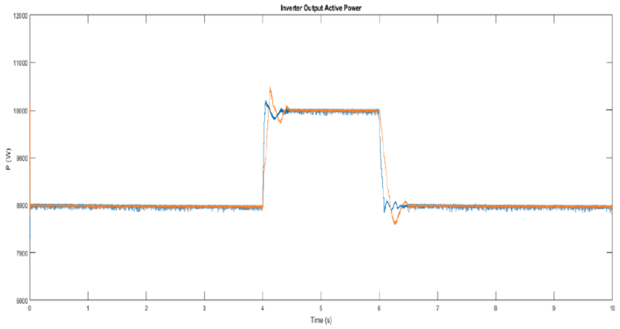
SL. NO	Insolation (W/m^2)	Output of PV array (V)	Output of the converter (V)
1.	1000	19.29	95.24
2.	900	18.21	83.21
3.	800	16.02	72.91
4.	700	14.08	65.37
5.	600	13.04	56.26
6.	500	11.92	47.09

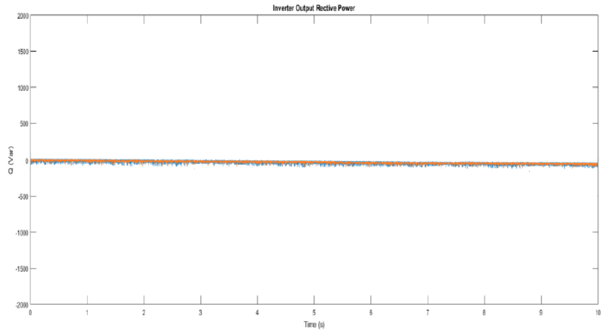
3.1.3 Matlab Simulation Circuit

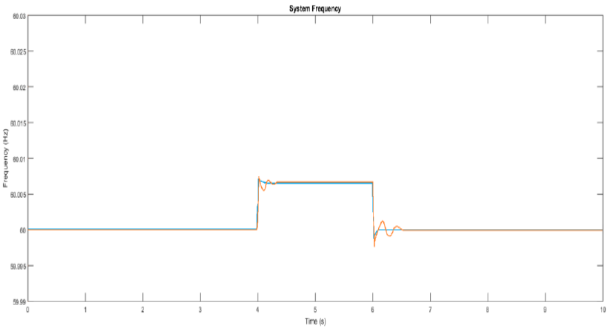


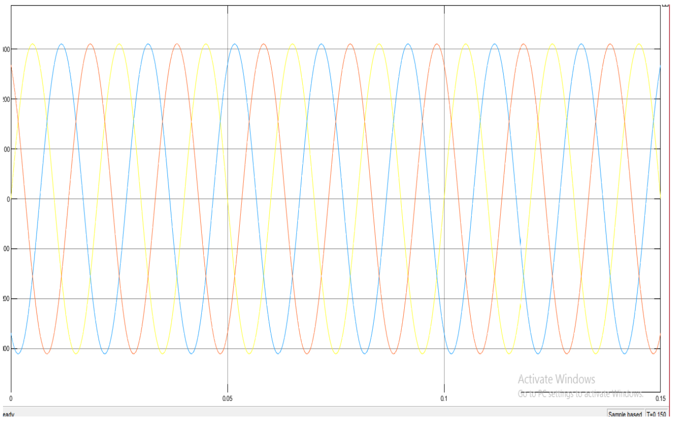


3.1.4 Matlab Simulation Output waveforms









4. CONCLUSIONS

The state-of-the-art studies on predictive control in microgrids have been evaluated in this study. The fundamental principle of predictive control is taught first. Following that, recent converter- and grid-level technologies are examined. These predictive control algorithms have been used in the hierarchical control of microgrids at three different control layers. Major advantages have been noted, such as faster dynamic reactions at the lower control level and flexible integration of diverse objectives at the higher control level. Predictive control's current issues and limitations have also been examined. Finally, future prospects for this developing field have been discussed.

The authors believe that, with the ongoing development of power electronic techniques and the increasing penetration level of distributed renewable energies into the existing power network, more advanced predictive control with new mathematical formulation and holistic intelligent scheme will play a significant role in microgrids, particularly in promising areas such as dc microgrids and networked microgrids. One of the most significant disadvantages of MPC is the impact of model parameter errors on system performance. The influence of uncertainty on the filter inductance value Ls and its resistance value RL is investigated in this work.

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