Contents

Part 1: Modeling and Simulation

Section 1

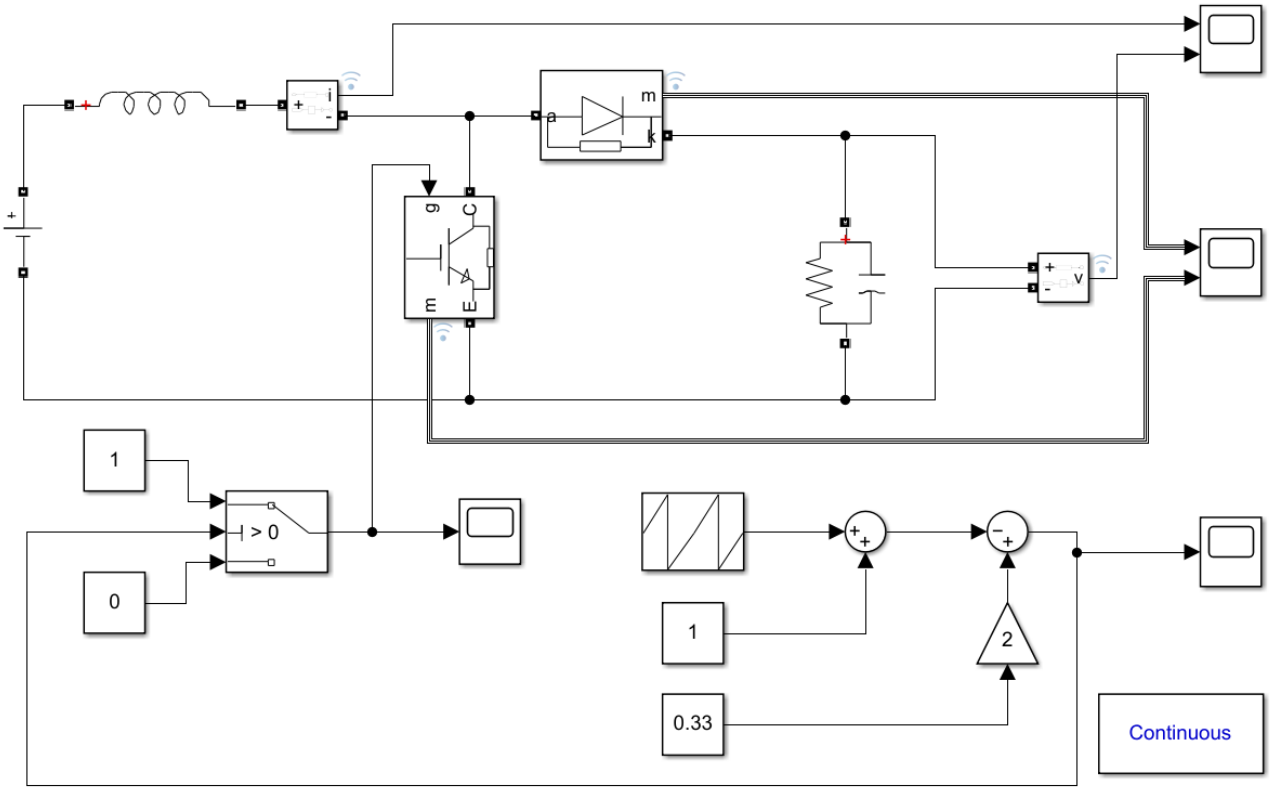


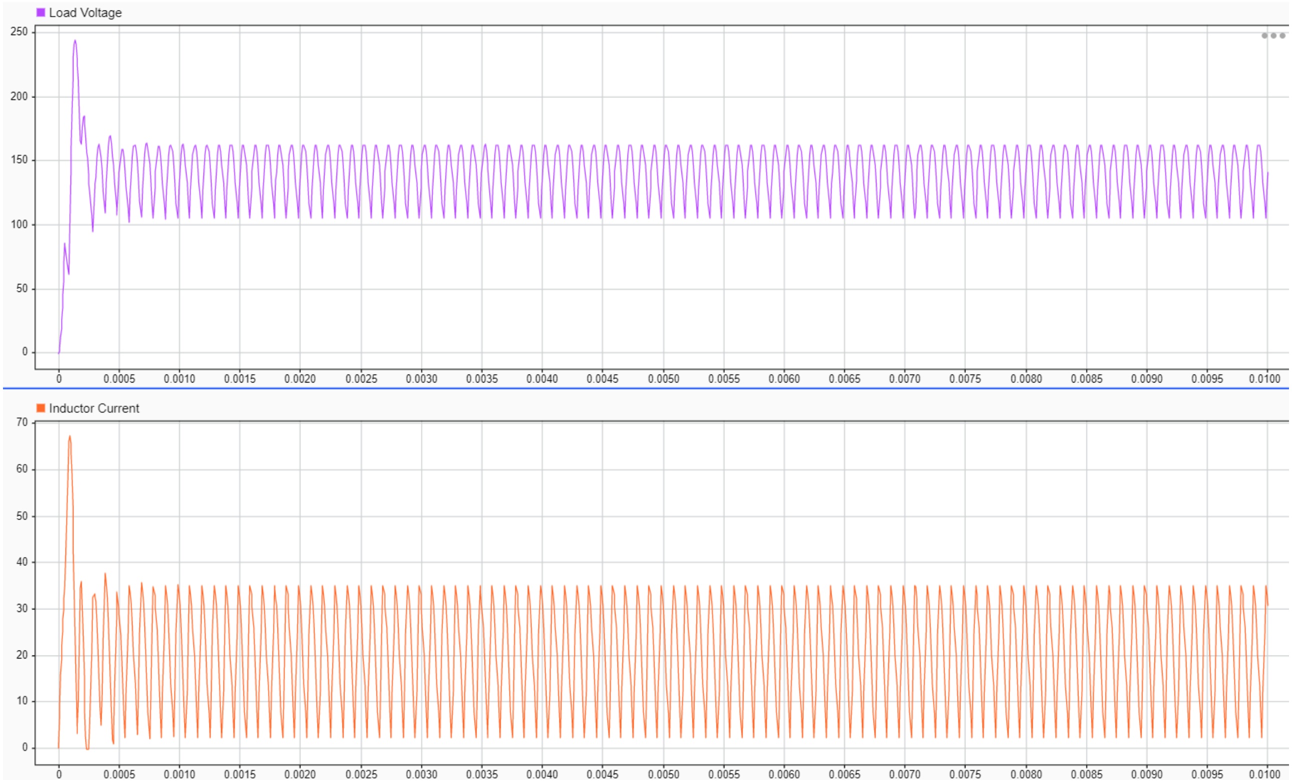
Figure 1: Boost Converter with RL Load (Open-loop control)

The next 10 pages show figures with the following information for each frequency and duty cycle:

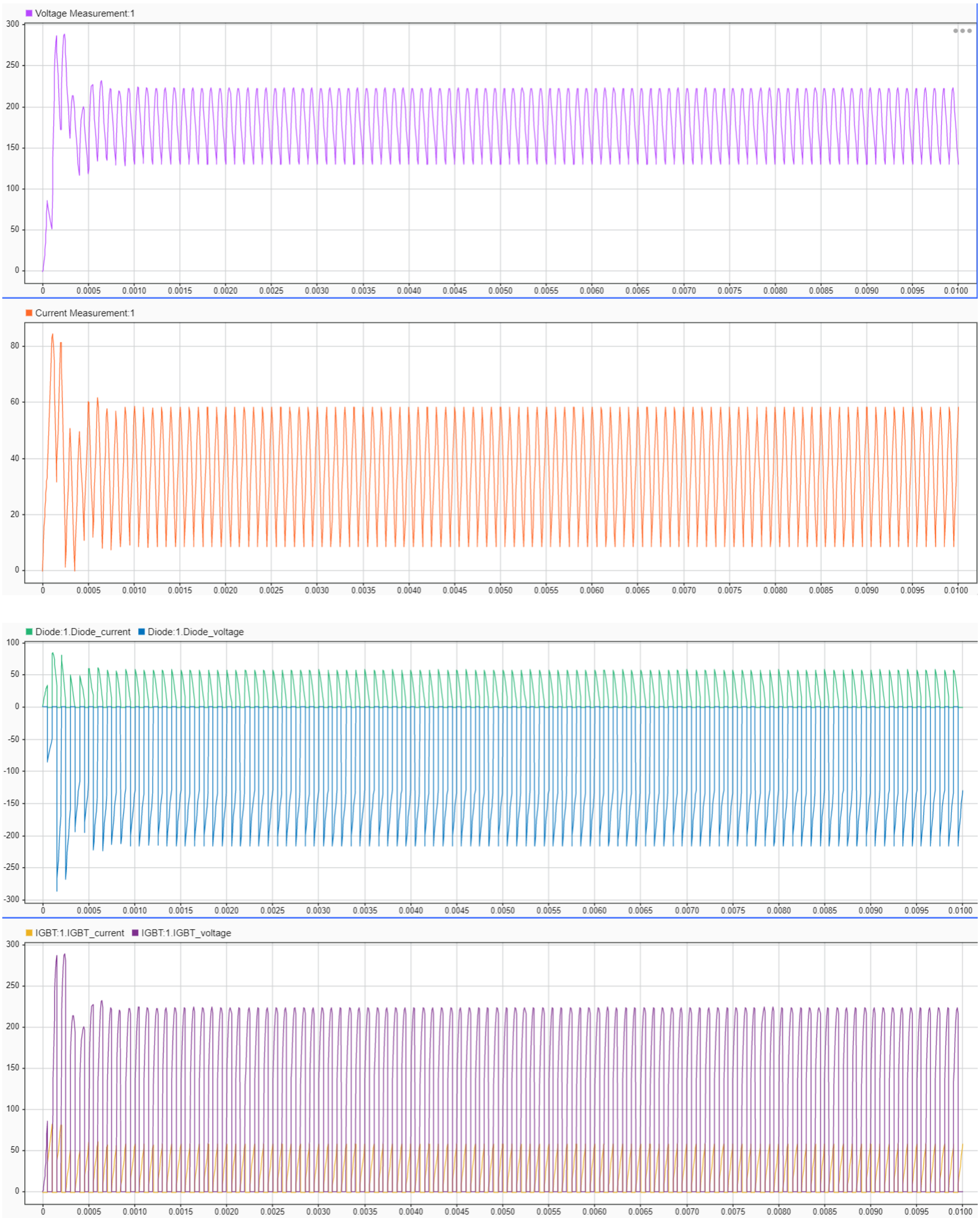
1. Load Voltage
2. Inductor Current
3. Diode Voltage & Current
4. IGBT Voltage
5. IGBT Current

In the exact order mentioned above

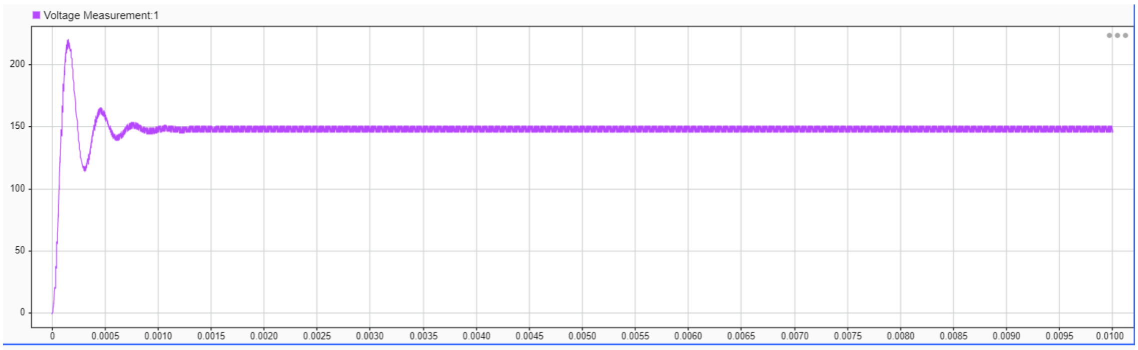
All the required parameters for 10KHz & 0.33 Duty Cycle

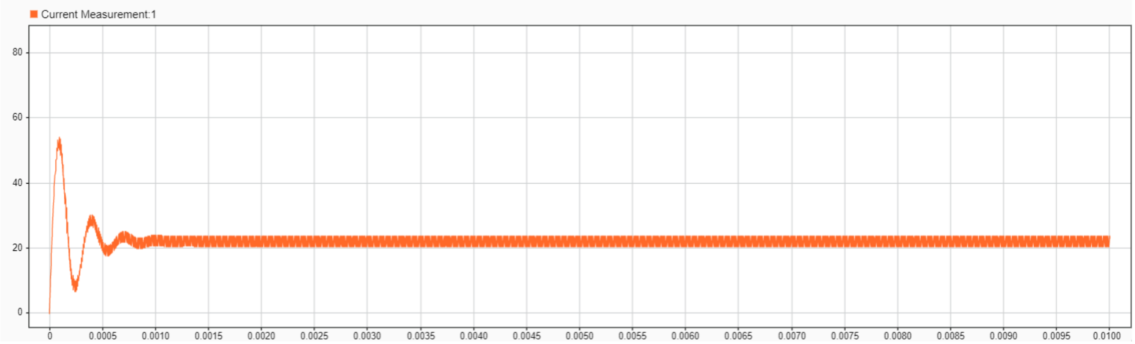


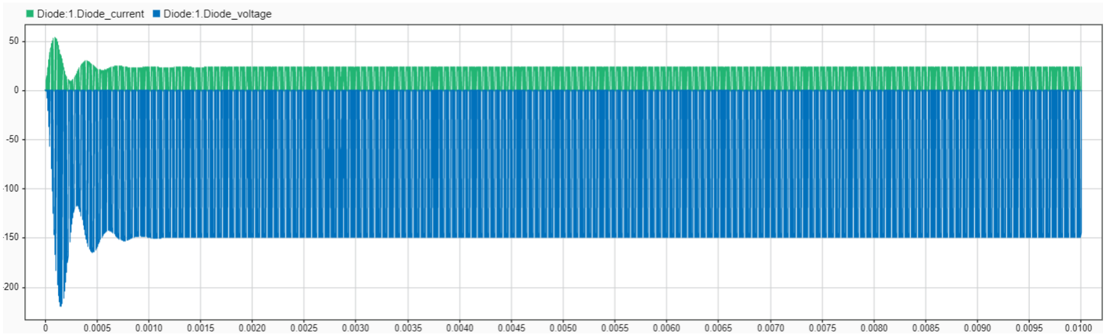
All the required parameters for 10KHz & 0.5 Duty Cycle

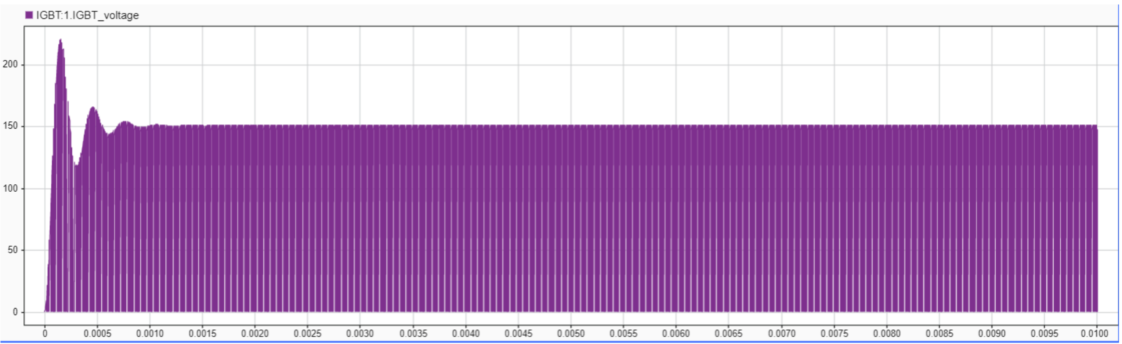


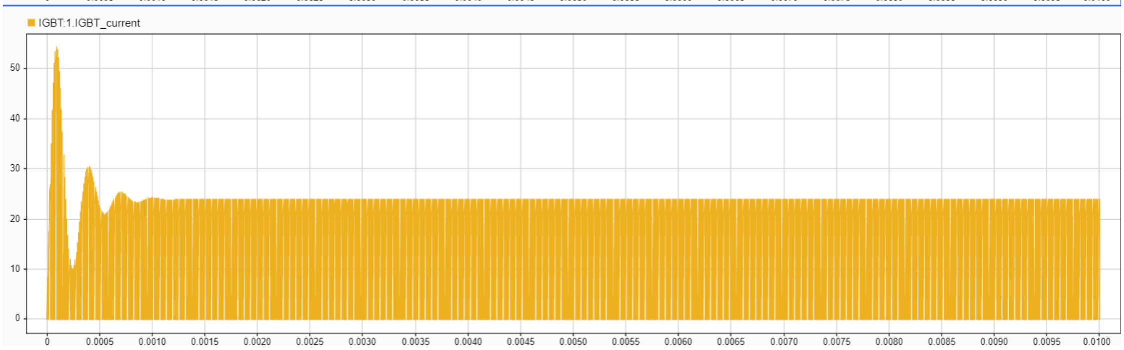
All the required parameters for 100KHz & 0.33 Duty Cycle



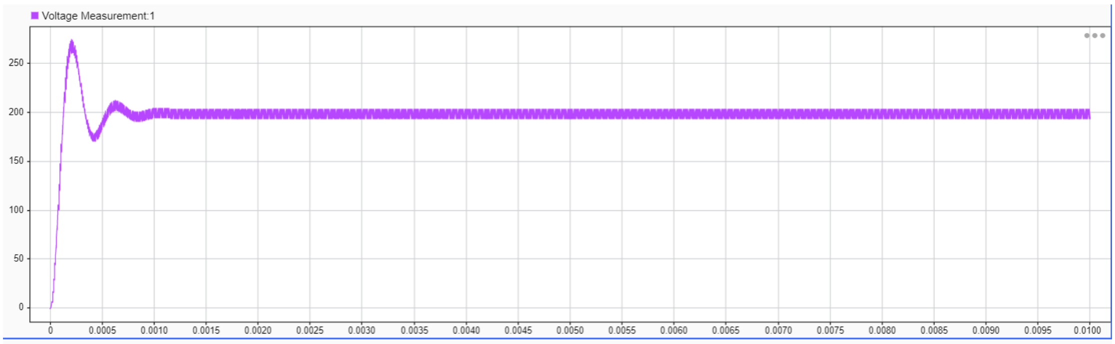


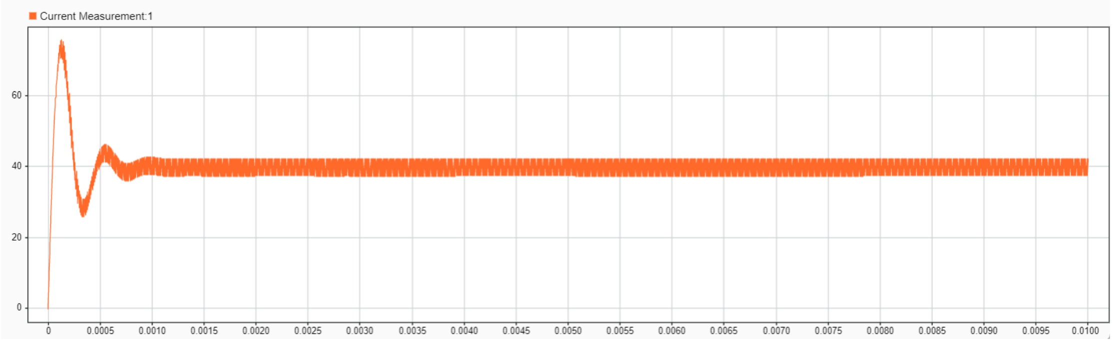


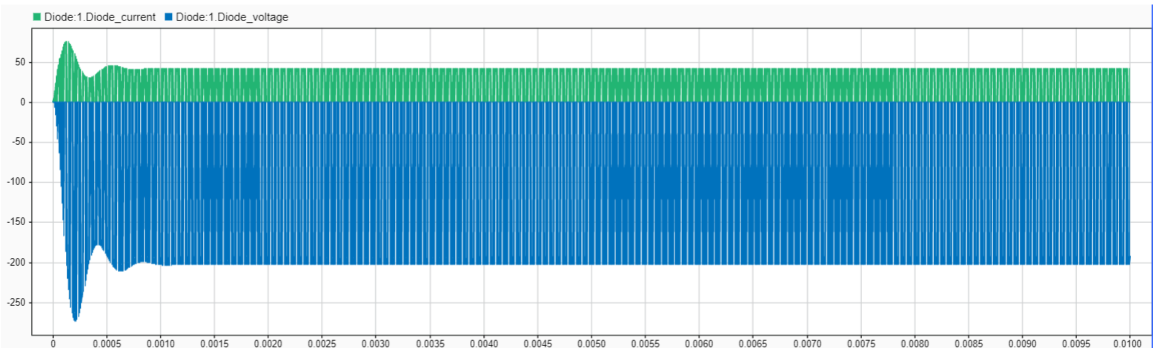


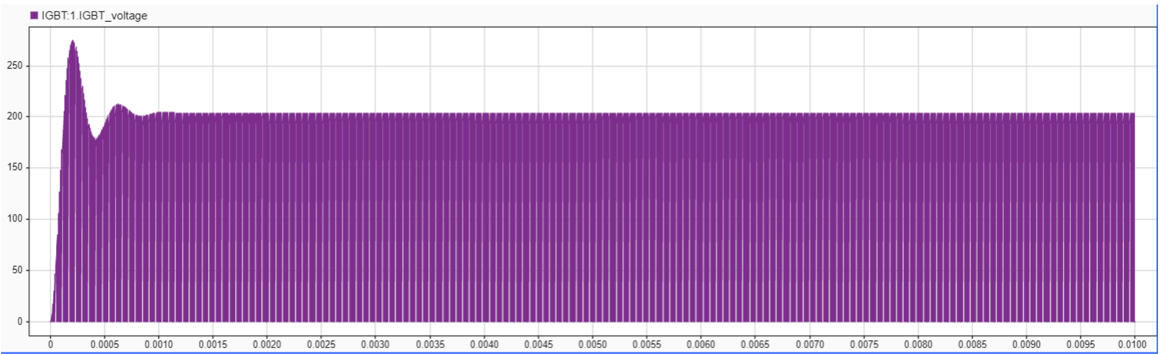


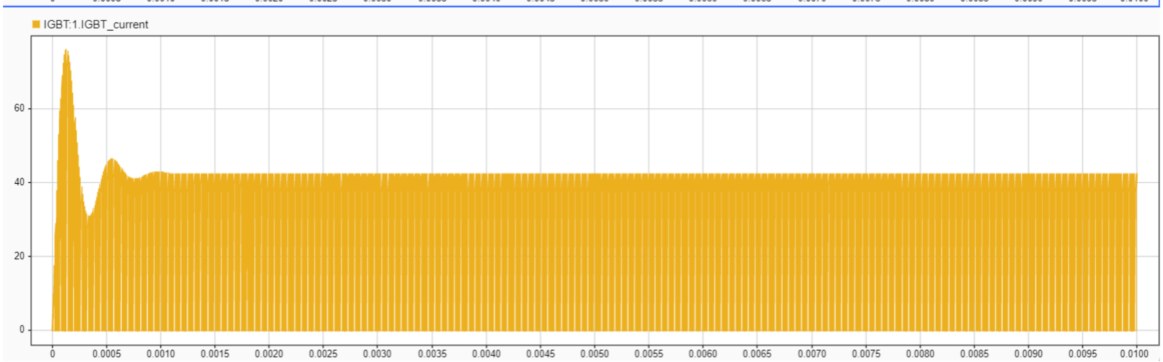
All the required parameters for 100KHz & 0.5 Duty Cycle



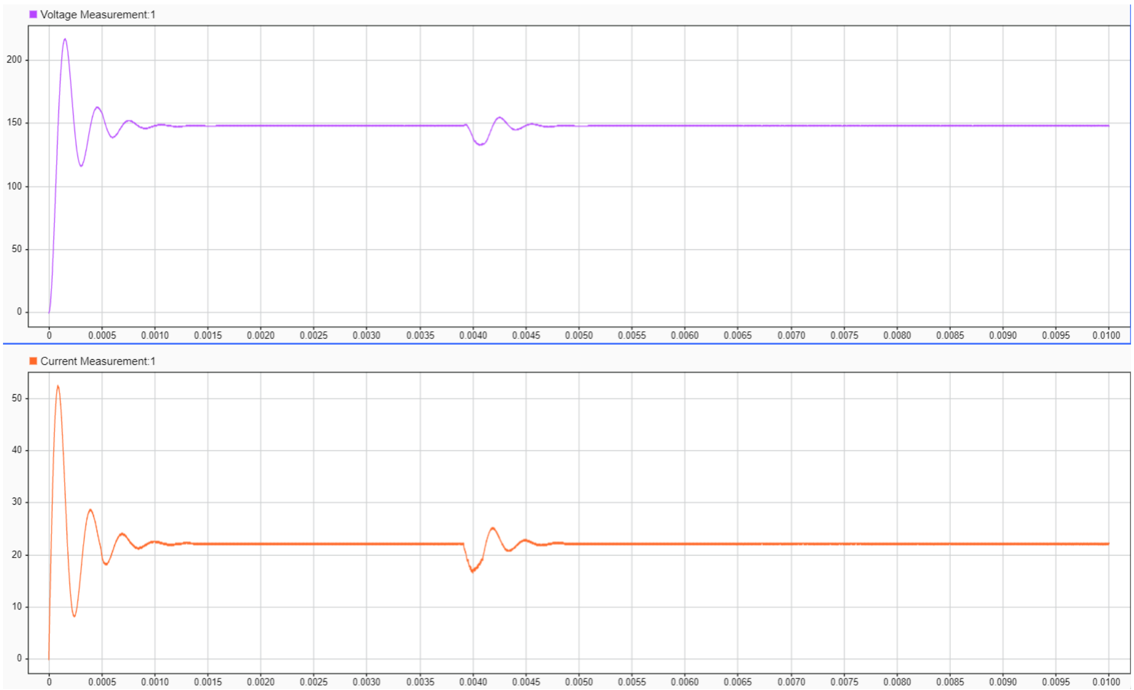


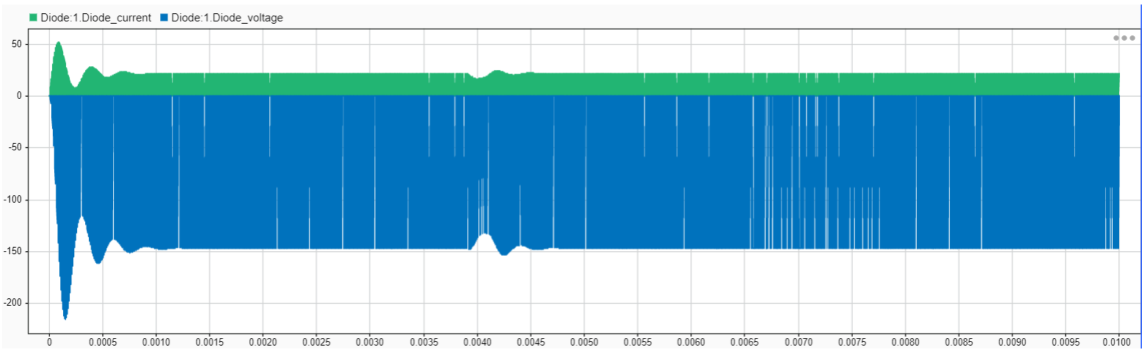


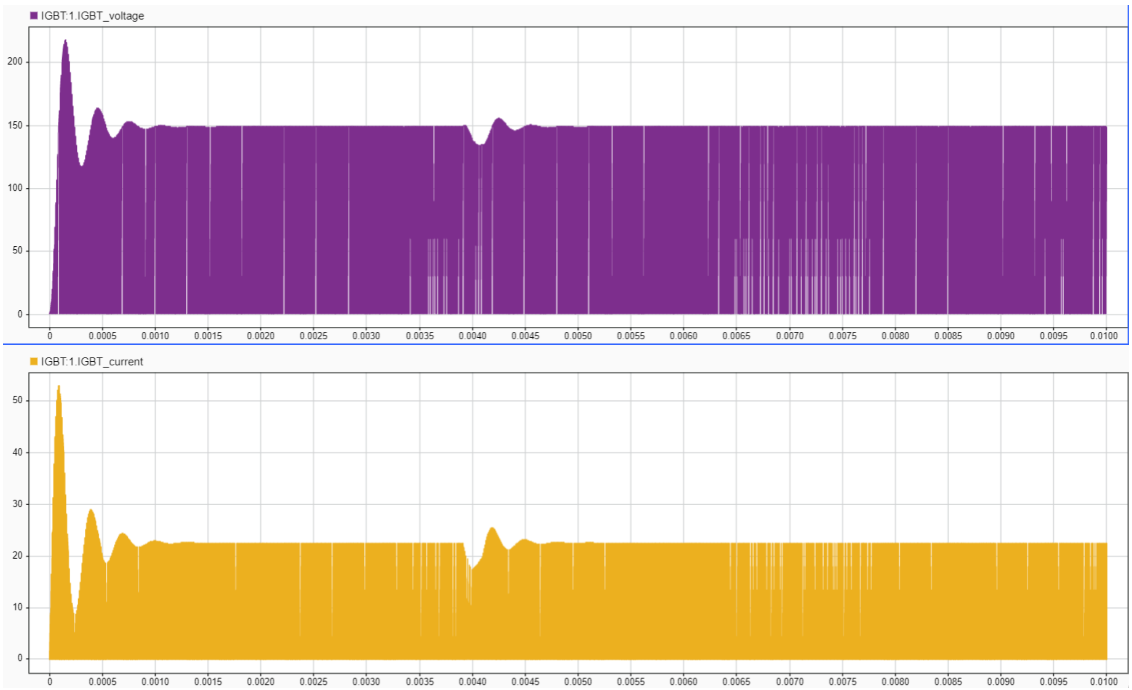




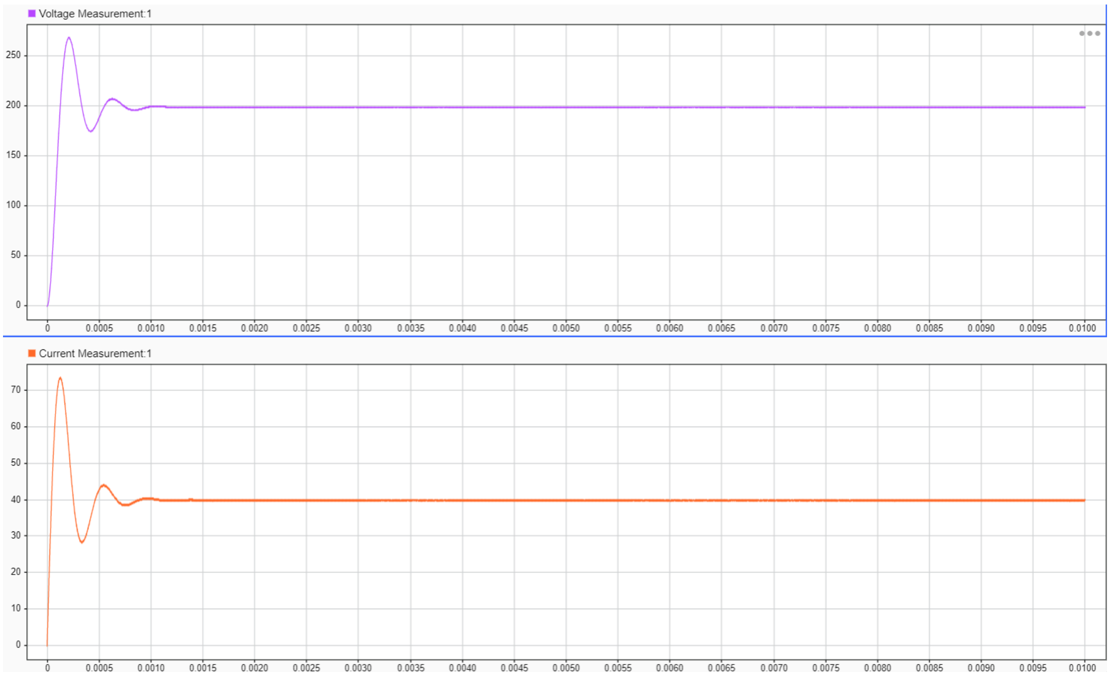
All the required parameters for 1MHz & 0.33 Duty Cycle

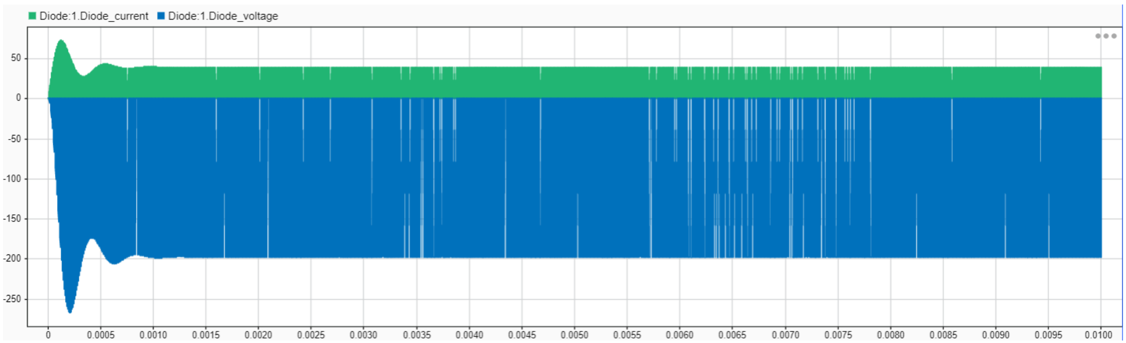


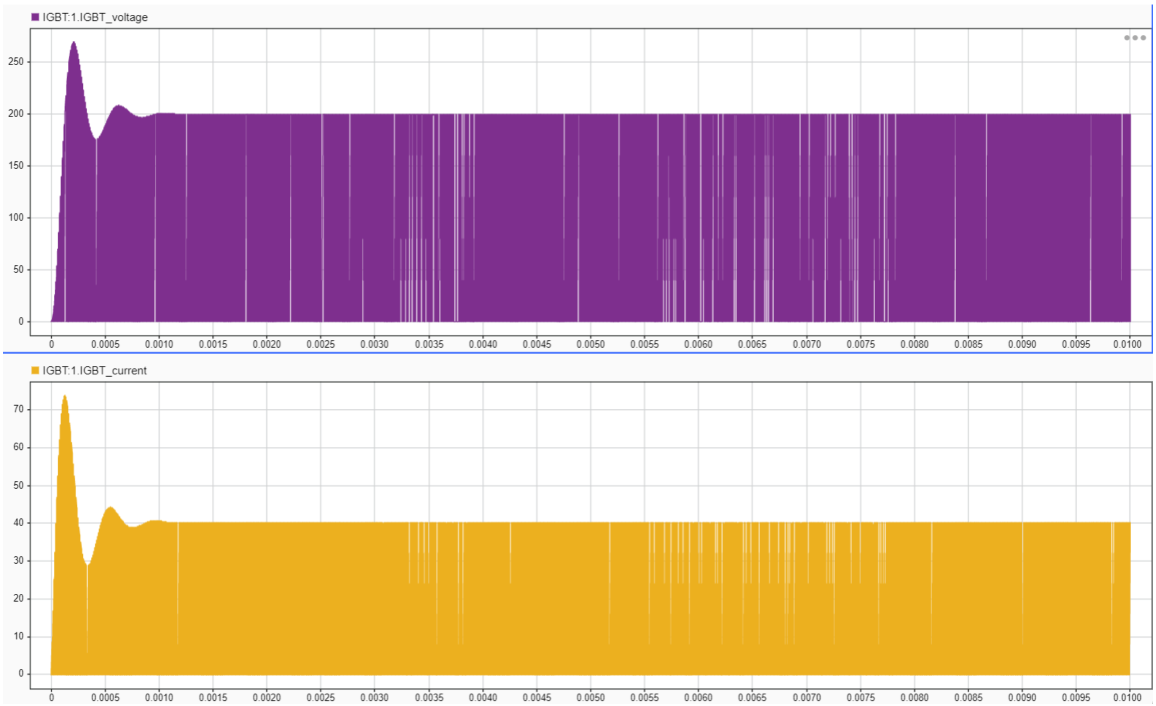




All the required parameters for 1MHz & 0.5 Duty Cycle







Section 2

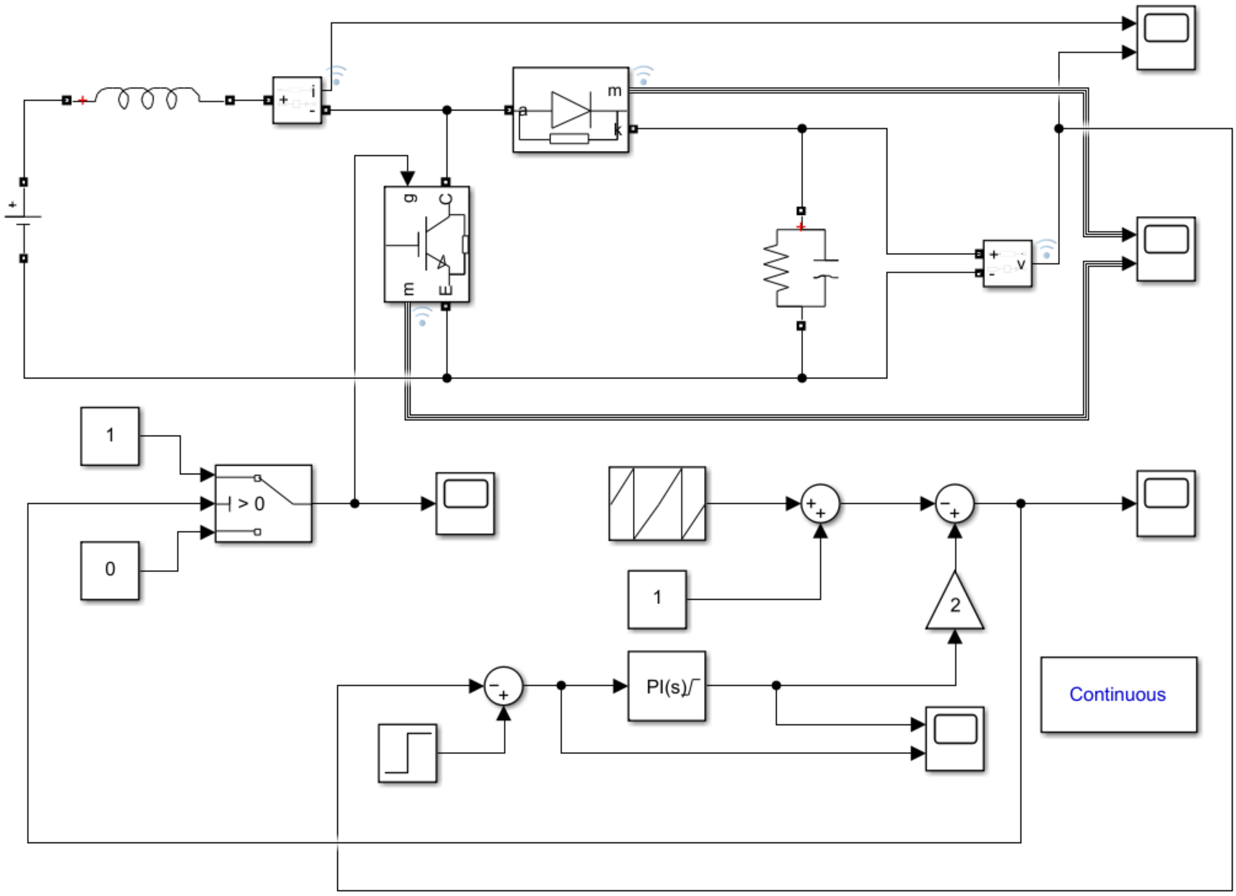
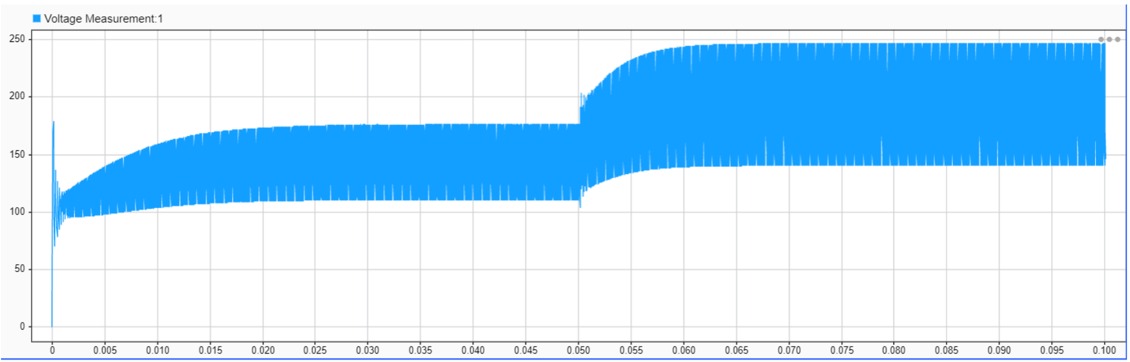
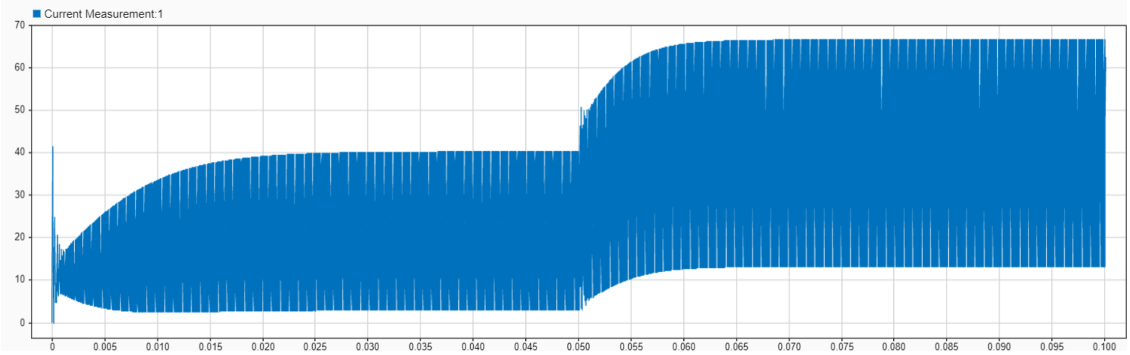
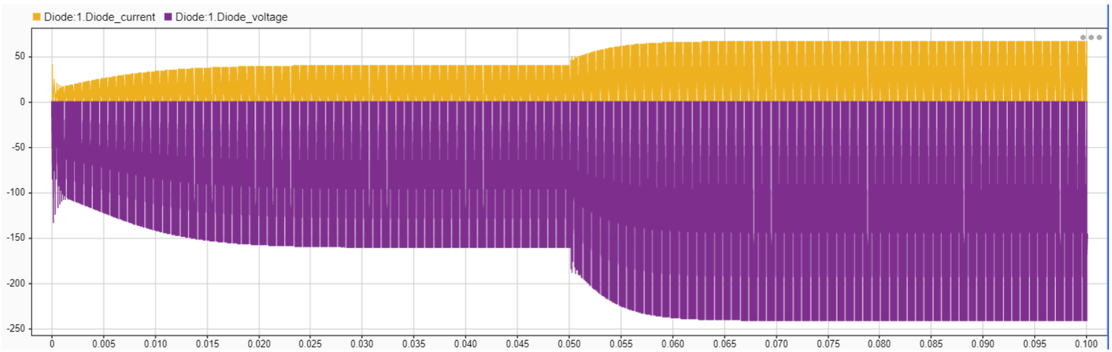


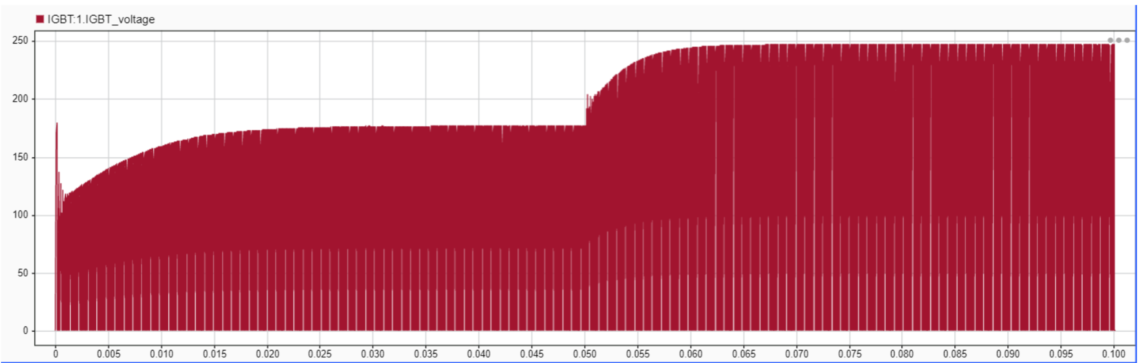
Figure 2: Boost Converter with RL-Load (Closed Loop Control)

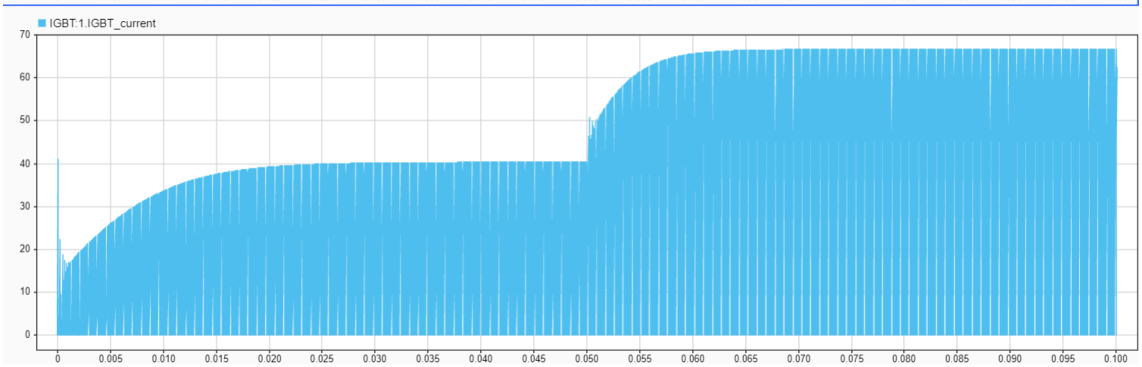
All the required parameters for 10KHz



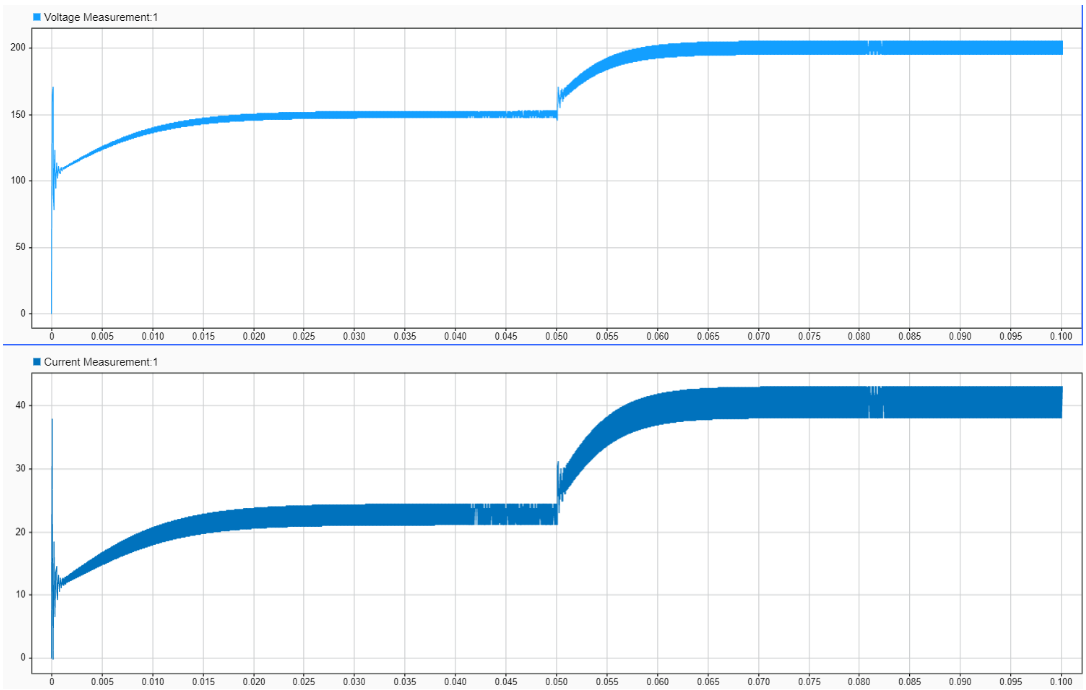


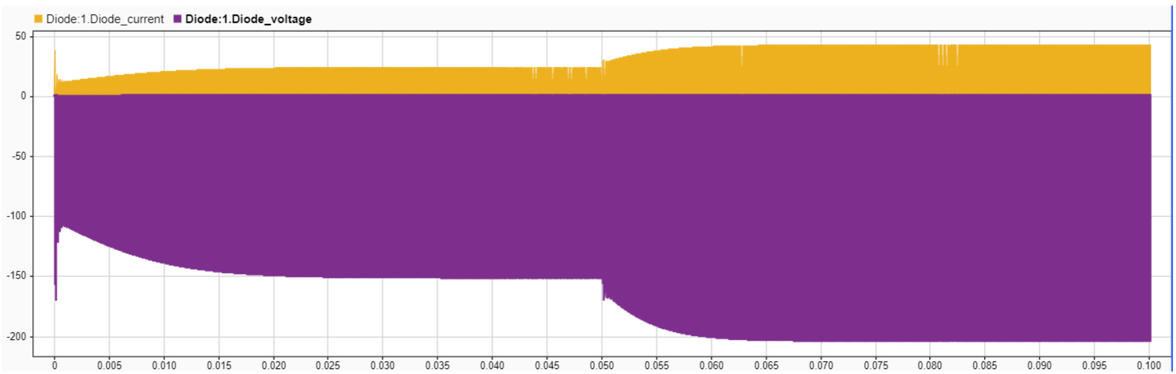


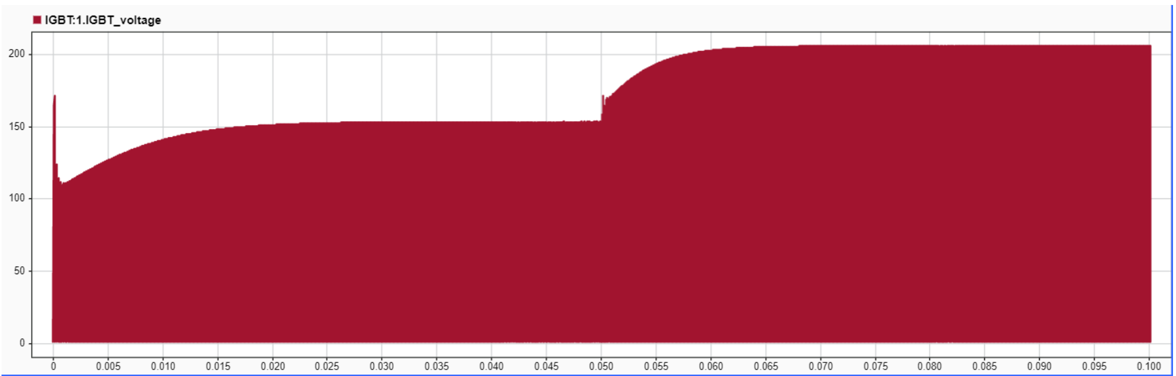


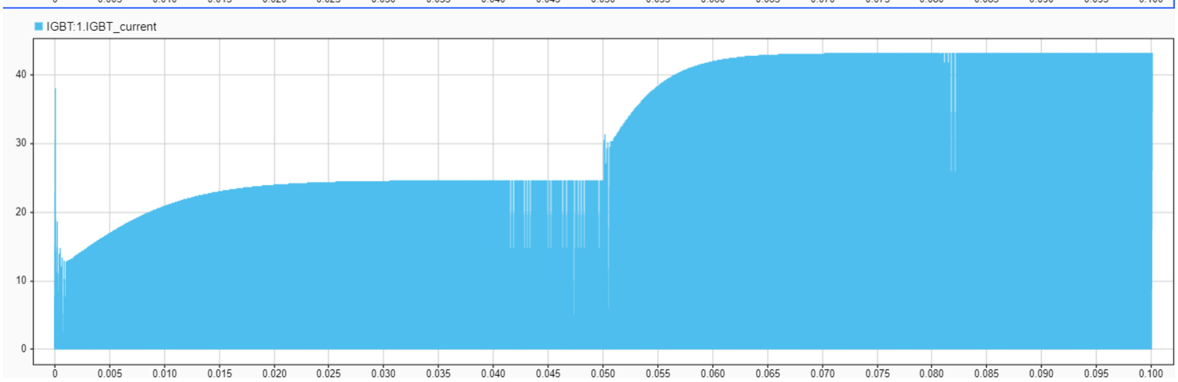


All the required parameters for 100KHz

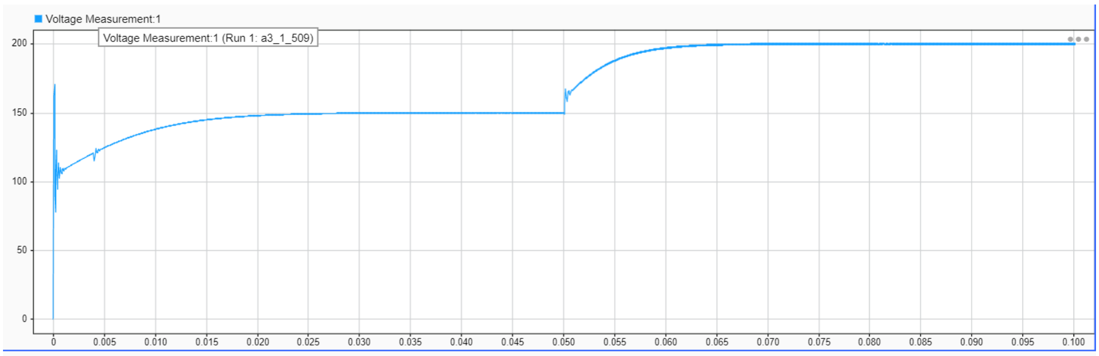


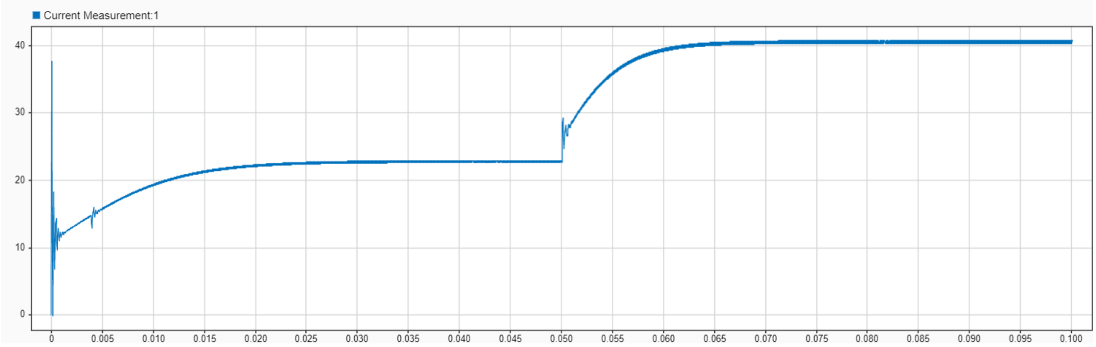


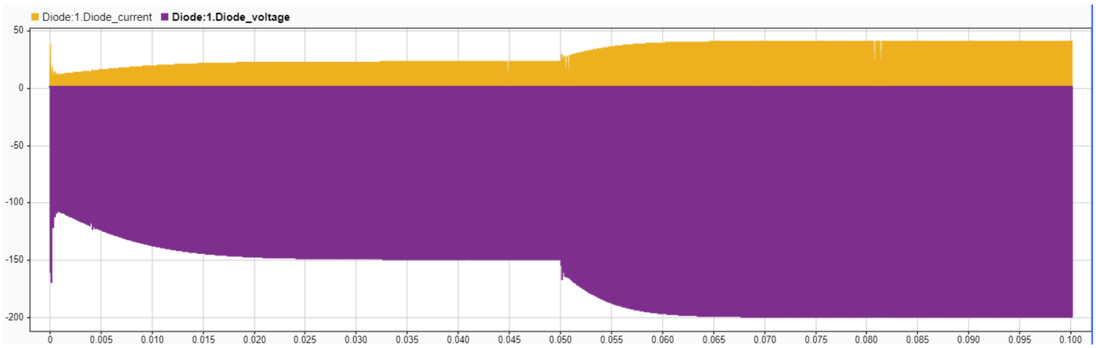


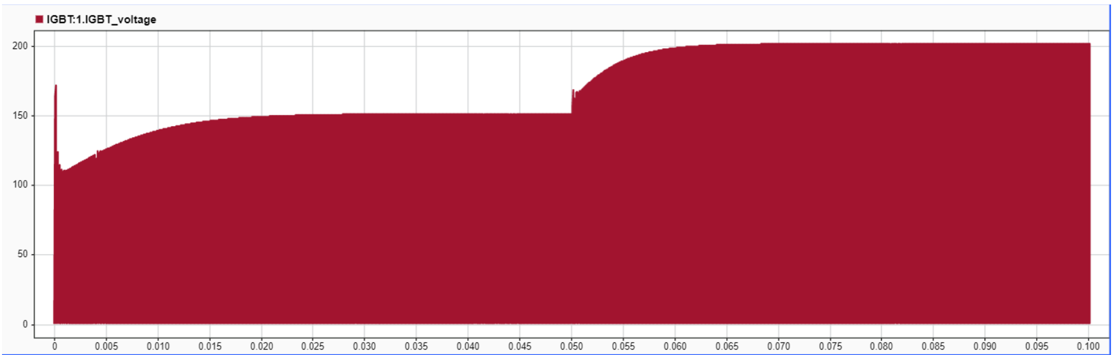


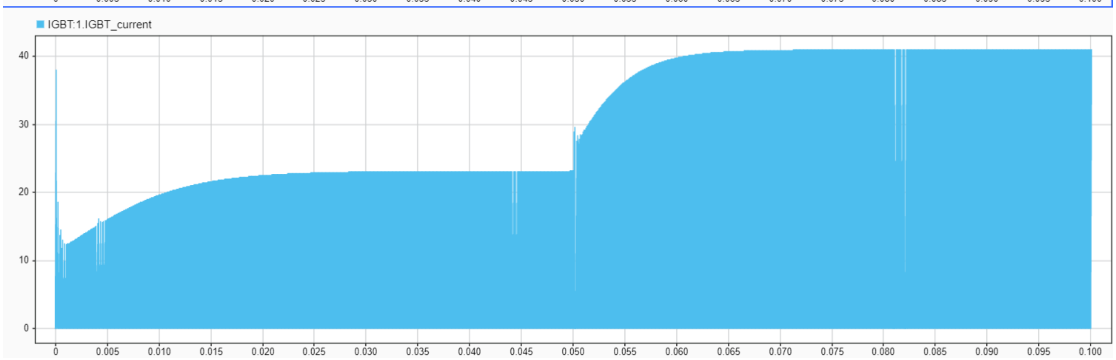
All the required parameters for 1MHz











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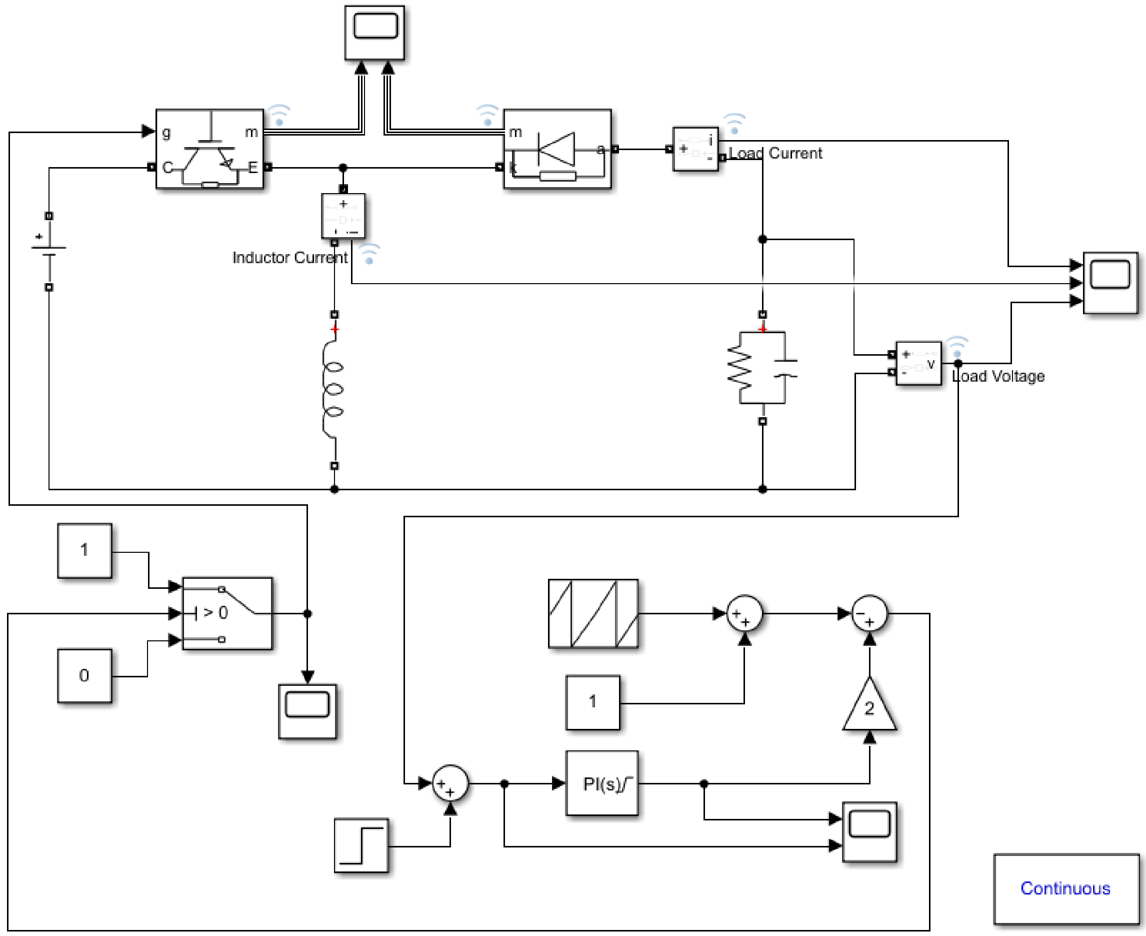
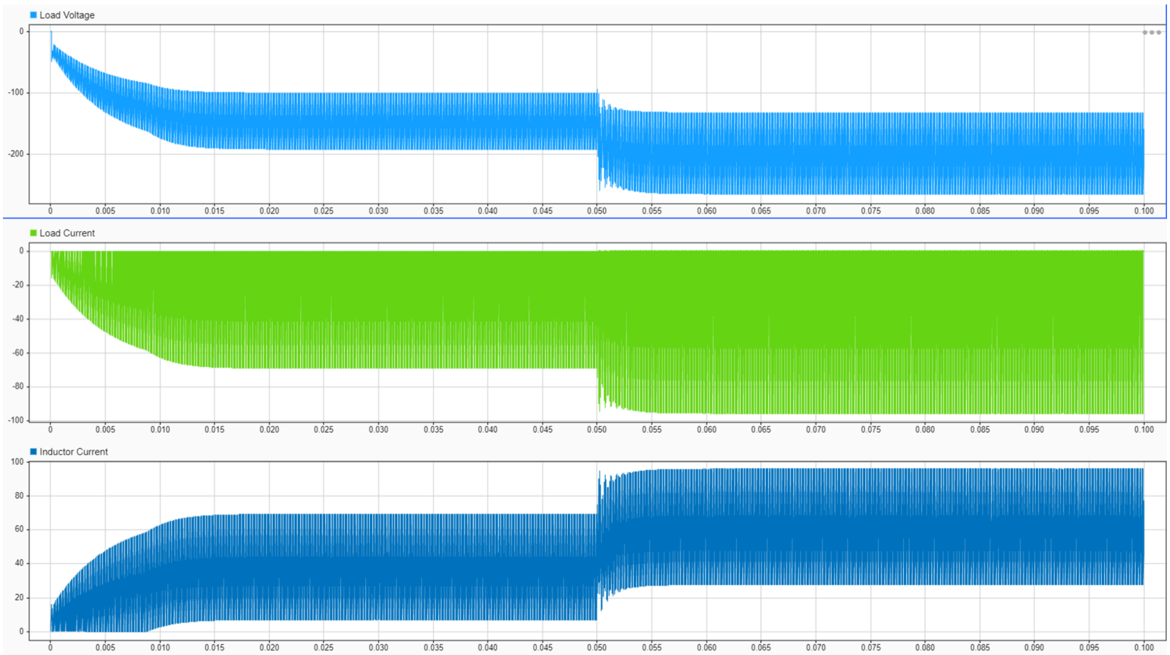
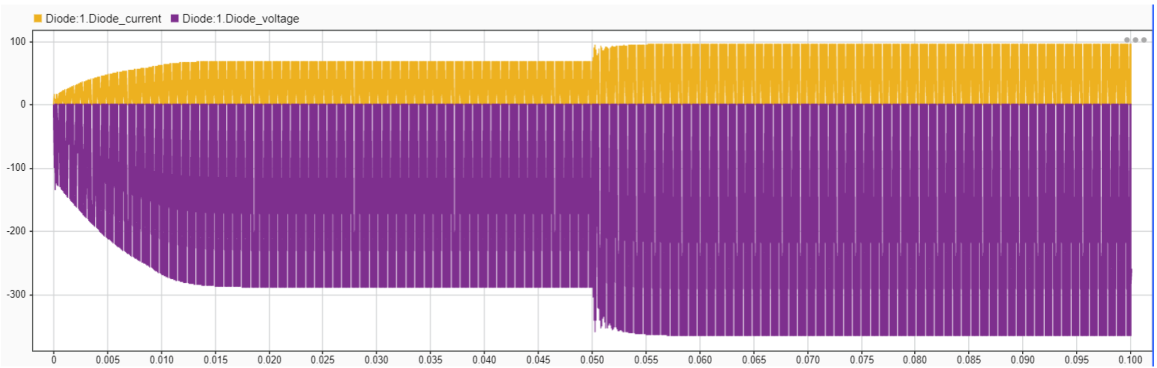
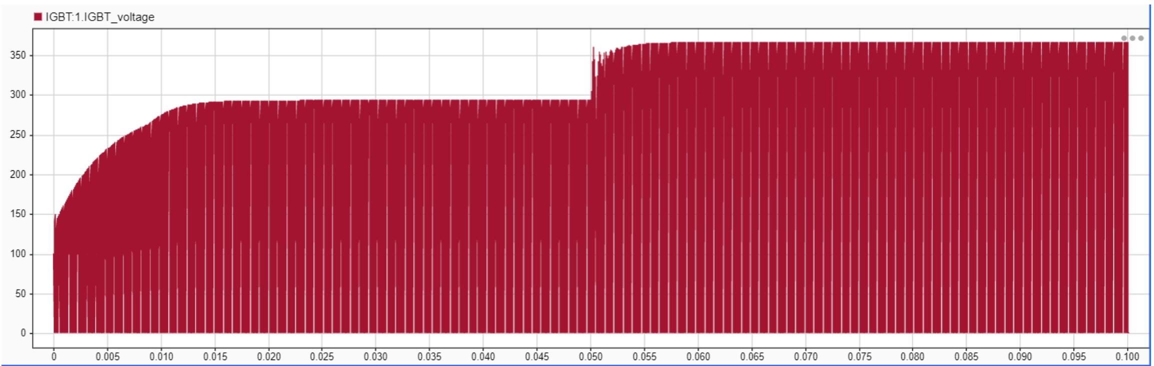


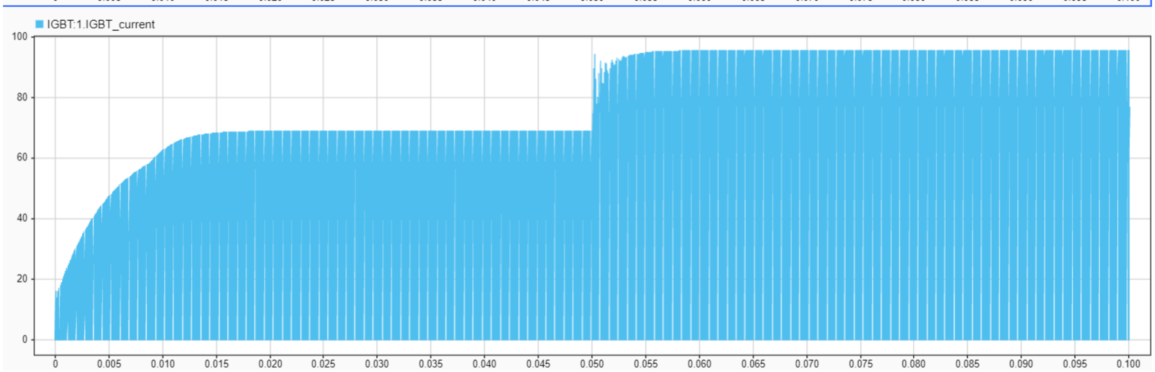
Figure 3: Buck-Boost Converter with RL-Load (Closed Loop Control)

All the required parameters for 10KHz

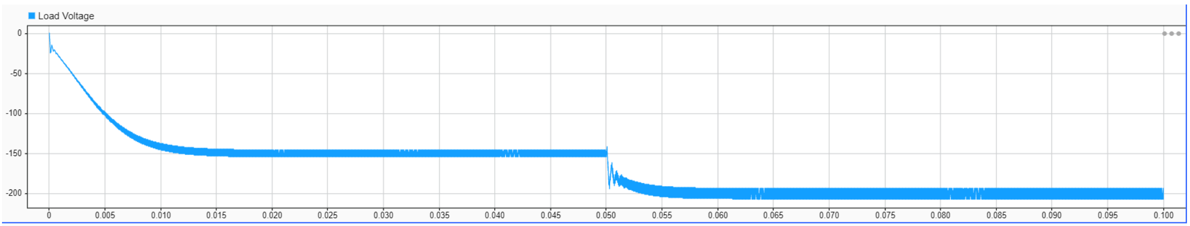


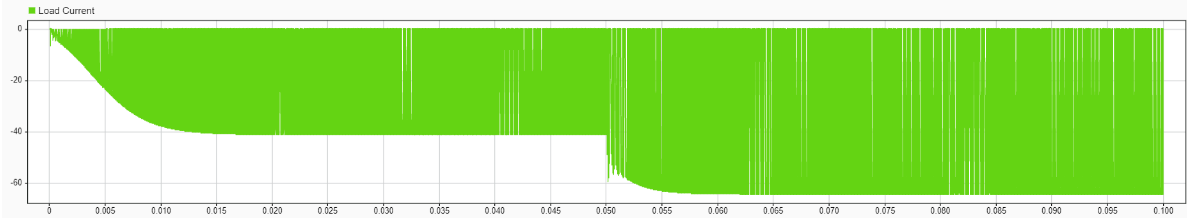


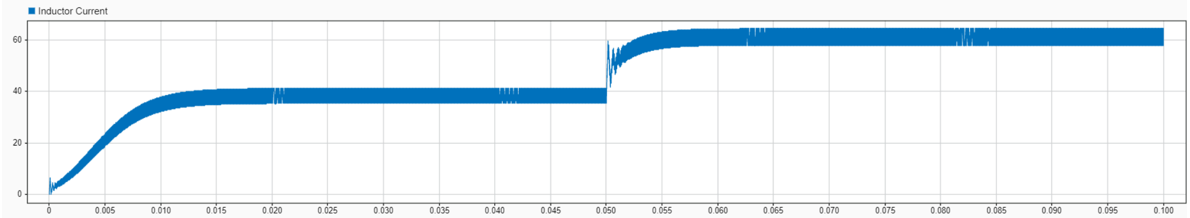


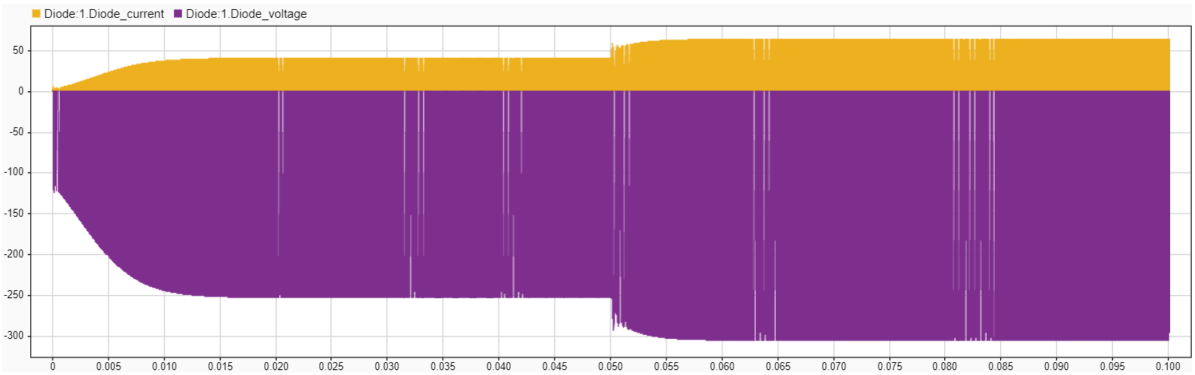


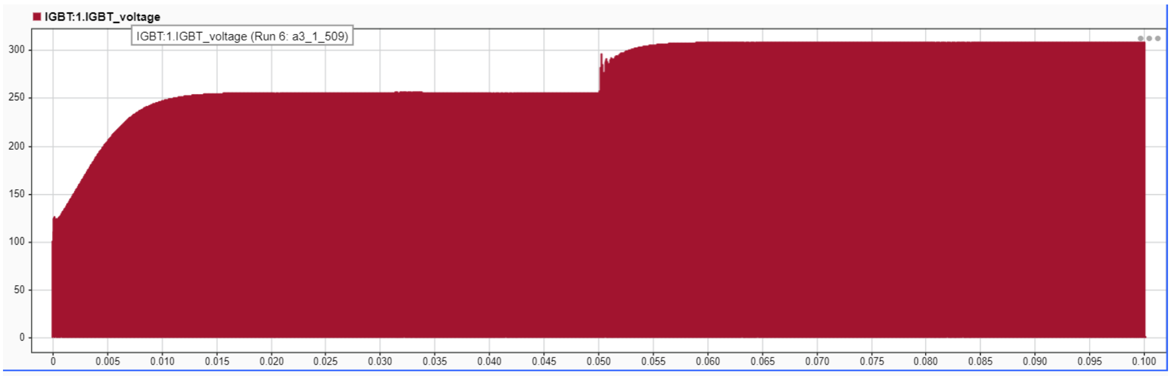
All the required parameters for 100KHz

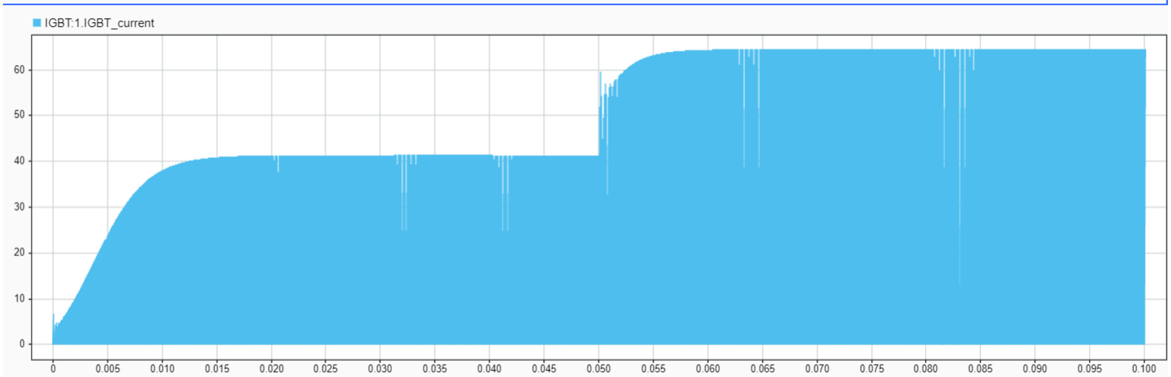




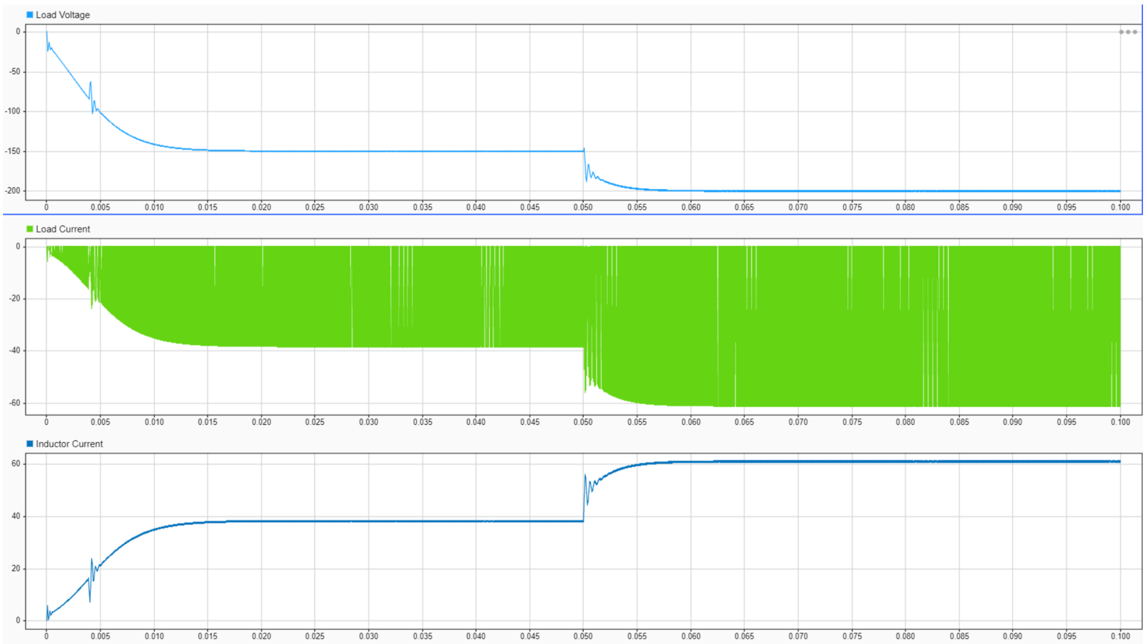


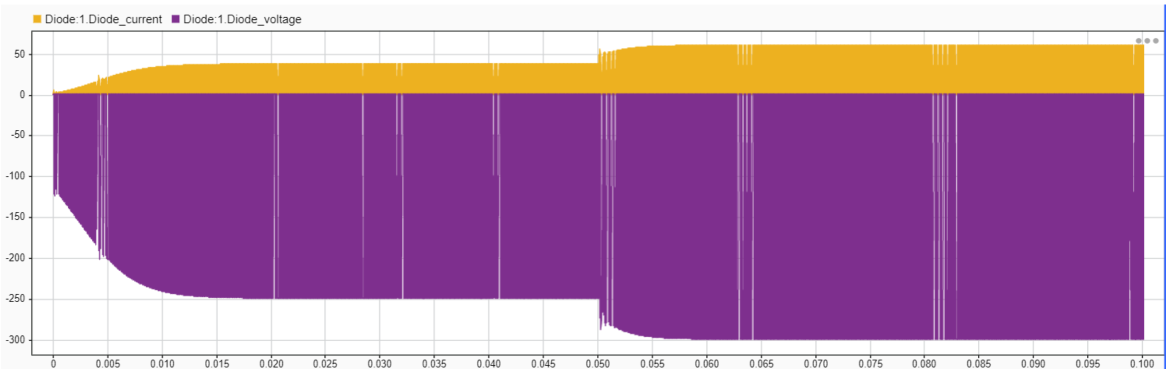


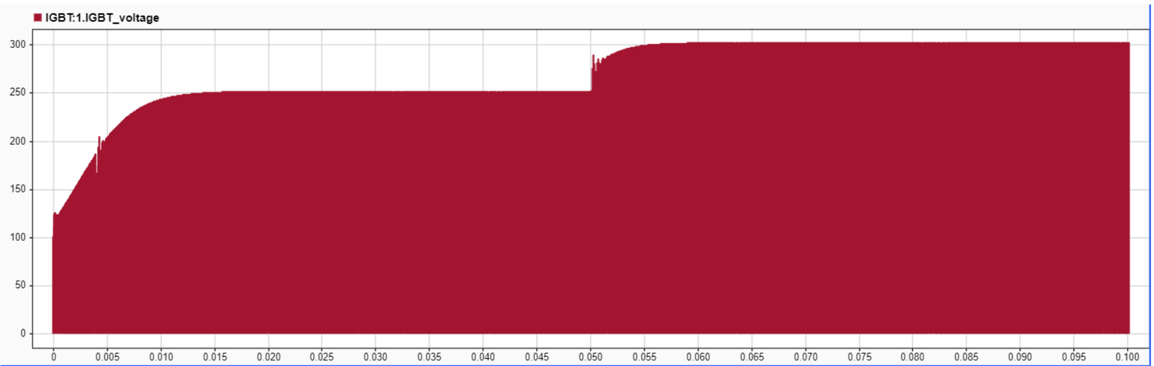


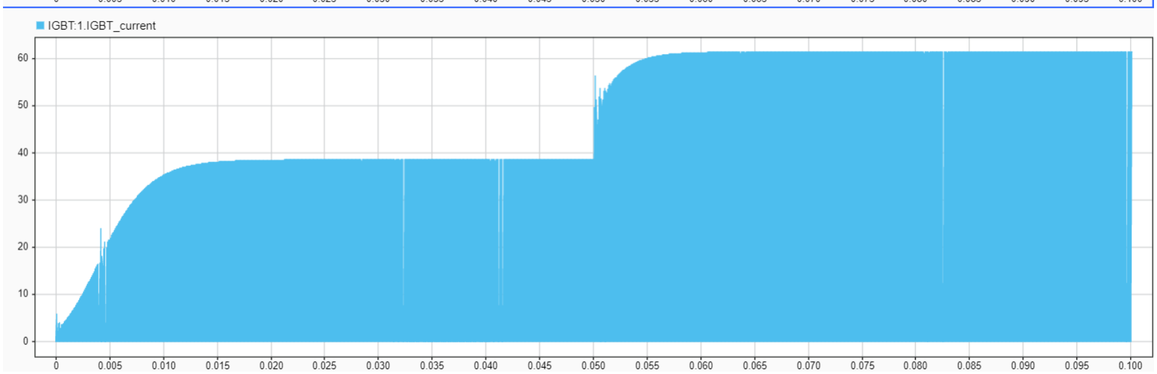


All the required parameters for 1MHz









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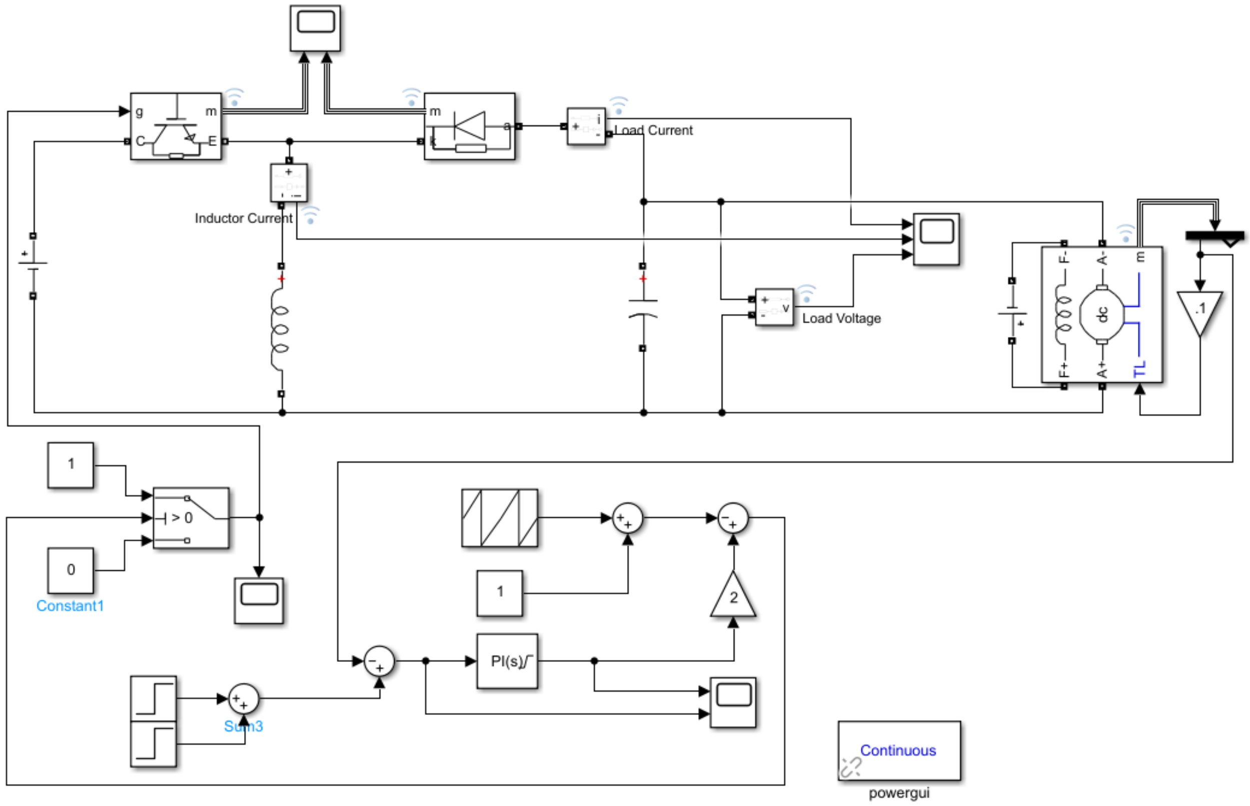

Figure 4: Buck-Boost Converter with DC Machine (Closed Loop Control)

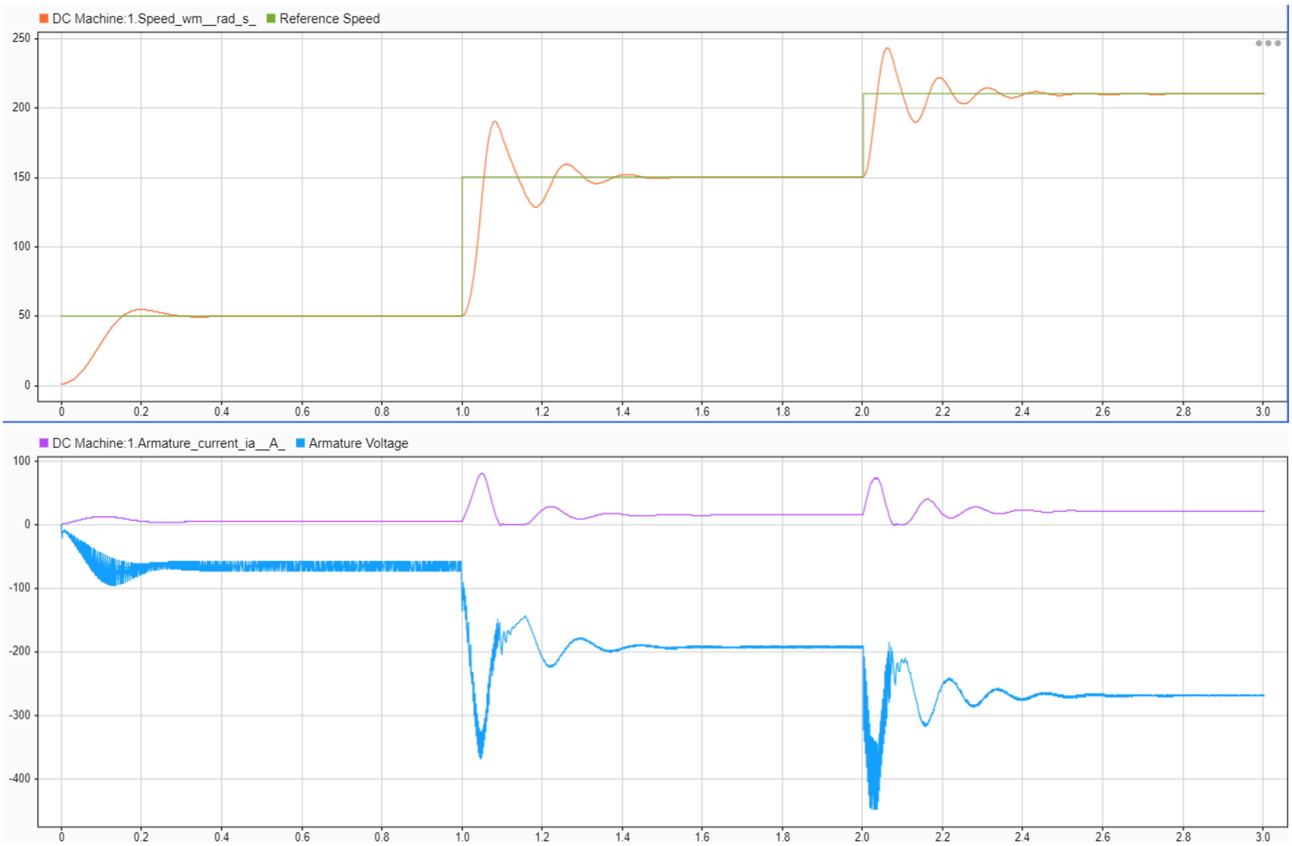

Figure 5: Response curves for switching frequency of 100 kHz

Part 2: Literature Review on Power System Protection

Question (a)

A. Shobole, M. Baysal, M. . Wadi, and M. R. . Tur, “An Adaptive Protection Technique for Smart Distribution Network”, *ELEKTRON ELEKTROTECH*, vol. 26, no. 4, pp. 46-56, Aug. 2020.

Question (b)

Future distribution networks, or ‘smart grids’ are anticipated to be flexible towards and accept renewable energy sources with ease. Existing distribution networks are bus networks with a radial distribution scheme at each distribution node, but due to Distributed Generation (DG), they become an interconnected hybrid network where the direction of power flow is bidirectional instead of unidirectional (Current distribution networks). This has serious implications in the power flow of the system as the number of DGs increase. The typical power system protection setup cannot address changes in behavior of fault & load currents and fault voltages that are caused by integration of DGs into the network. These changes in the fault current at each node generally show an increasing trend (This might not be the case for every system). To address this problem, a new protection philosophy is devised which adapts to the type of the network by monitoring the status of the Circuit Breakers (CB) in real-time using Intelligent Electronic Devices (IEDs). Monitoring CB parameters & carrying out calculations constantly allows relaying systems to update their settings simultaneously with the changing nature of the power system. The protection philosophy can allow CBs to adapt to varying amounts of fault and load currents in the system creating a secure grid with added flexibility towards integration of new DG technology. In a nutshell, this protection scheme allows users with their own renewable energy sources to plug-and-play with the grid. The philosophy can be valid for any amount of DG integration into the grid, verified through DigSILENT PowerFactory software using DigSILENT Programming Language (DPL) to model the system.

Question (c)

The article suggests an improved protection philosophy for intelligent distribution systems of the future. Due to usage of renewable technologies by various organization, agencies & individuals, existing radial distribution systems will soon be converted into multi-source networks. Multi-source networks add another level of complexity ito the system by changing its short-circuit fault current. Current systems without DG have a relatively straightforward fault behavior that is dependent on the fault impedance and the distance of the fault from the feeder. But systems of the future might have generation systems with different levels of integration in each distribution cluster as a part of the global shift towards sustainable energy. This is certain to create larger fault currents which the existing CBs can't handle. Current CBs are made of over-current relays that are selected after conducting short-circuit analysis on the existing distribution system. Such relays are not adjustable which wasn't a requirement for the existing grid. Existing solutions like differential relays protect the system from internal faults if parameters deviate from steady-state conditions. Directional relays protect the system in case of power flow in a certain direction only. These protection schemes are reliable solutions in case of fixed generation, DG or not. But most DG systems are either wind or solar based. Their generation capability is highly dependent on the environmental variables like wind speed and solar irradiance, making generation quantities as non-linear as the load profile of the power system which makes the protection schemes specified above unreliable. The authors propose a new solution which adapts to such changes in the power generation by the DG system and change CB settings to match with the existing state of the system. Such a task isn't possible or practical unless the adaptive system is real-time.

The authors suggest a real-time monitoring system to monitor the system parameters, conduct load-flow (LF) and short-circuit (SC) analysis within each sampling period and update the CB settings according to the current state of the system. The protection philosophy is made of 4 parts, namely; monitoring, detection, analysis & communication. All the parts are embedded within IEDs that are a part of each CB relay. The monitoring system observes necessary parameters and the detection system has an XOR-logic based state change detection system. The detection system is centralized, so it must communicate with each relay. As soon as the system detects change, central controller signals end relays (at the feeder) to turn adaptive mode on. Initial settings are loaded onto the end relay and the relays upstream and downstream from it perform calculations relative to it. The relays conduct LF & SC for each sampling period and update each upstream and downstream relay, following the algorithm shown in the paper. As a result of these calculations, the relays change their Time Multiplier Setting (TMS) to **change** the **pickup current of** the **relay by adjusting contacts**, which is the **core physical layer of the adaptive part** of the sytem. These settings are also adjusted such that self-clearing faults get enough time. These relays follow two unique coordination processes for many-to-one and one-to-many configurations. For the many-to-one configuration, the downstream relay selects the max TMS from the upstream relays and sends a signal to change the configuration setting of every other relay to that max value. In the one-to-many process, downstream relays conduct analysis and send signals to the upstream relay with their required parameters and the modifies the settings of the downstream relays to match their exact requires while it itself sums the requirements to update its own settings.

All of these are modeled by using a real-life grid in Antalya, Turkey. Various PV power plants with a cumulative capacity ranging from 4 MW to 15 MW are integrated into the grid and their effects on the proposed philosophy is observed. The philosophy correctly updates the CBs settings for each level of integration and verifies the model. The only downside being false tripping of relays due to PV plants.

Terminology

Upstream – Circuit that feeds the CB
Downstream – Circuit that is protected by the CB
Pickup Current – Current required to trip the relay
TMS – A constant which decides the time required for a relay to trip