Many engineering and Industrial applications nowadays involve complex processes which require accurate and speedy estimation of important boundary conditions, properties and process parameters for analysis. The design, as well as the operation, and the quality assessment and control of various processes occurring in many thermal applications, often require precise knowledge of boundary conditions, properties and process parameters. In some situations, measurement of these quantities is very difficult because of unapproachable locations or sluggish measuring techniques. At present, however, the technique of the inverse heat transfer (IHT) has offered a convenient substitute to estimate the unknown quantities accurately and instantaneously, which significantly reduce the resources. In this work, some of the latest and efficient algorithms, one deterministic algorithm, Conjugate Gradient Method (CGM), and two meta-heuristic algorithms, Ant Colony Optimization (ACO) and Salp Swarm Algorithm (SSA) are used to estimate the unknowns. One distinctive combination of predicting the characteristic profile of the variable boundary condition and estimating the corresponding profile parameters is also presented. This innovative methodology is conceptualised, and the corresponding codes are indigenously developed by the author. Inverse heat transfer problem (IHTP) techniques are good alternatives for the complex problems and in this work, two classes of complex problems, roof-mounted solar PV power plants and continuous casting process through billet, slab and thin-slab moulds are analysed.

Accurate quantification of variable properties and site-specific process parameters of roof-mounted solar PV power plants are essential for the design and development of the power plant as well as for the operation and maintenance and capacity improvement/reclaim of the power plant. In this work, a novel inverse heat transfer technique based on an efficient optimization method, Salp Swarm Algorithm (SSA), has been used to estimate the unknown properties and process parameters. This methodology has been proven to be efficient and has not yet been used for thermal applications which use limited on-site plant recorded data and consumes relatively less computational and experimental resources. Numerical and experimental analyses are carried out for the representative periods and the representative days. The observed results indicate that the location-specific process parameters can be estimated with reasonable accuracy and these results can be used to estimate the module temperature which, in turn, is used for an accurate estimation of power generated using temperature coefficients and healthiness of the system. The proposed methodology is simple to execute,

uses only limited experimental data and is recommended for studies aimed towards estimating the unknown properties and process parameters.

Inverse techniques take exorbitantly more time to predict the boundary conditions such as heat flux of a mould and most of the time, the results are fluctuating. In industrial casting applications, estimation of the thermal state of the mould using traditional methods, does not give the correct results within the stipulated time. A novel and innovative methodology of combining the theoretical and practical knowledge coupled with a new inverse technique is demonstrated in the present study to estimate the variable heat flux of a billet mould. This unique method predicts the characteristic profile of the unknown heat flux initially using the available knowledge from the literature or the function estimation IHTP method, CGM and then, estimates the corresponding profile parameters using a few sets of experimental observations, using a meta-heuristic algorithm, SSA.

Inverse heat transfer methods are typically employed to estimate the heat flux variation by assuming a one-dimensional variation of heat flux along the casting direction. The assumption of one-dimensional heat flux often leads to significant error, especially in determining the corner heat flux which affects the shrinkage behaviour and thereby, the quality of the products of casting. Prior studies have recognized this error and assumed this error of heat flux as a constant deviation to account for the longitudinal and transverse variation of heat flux. In this research work, a novel methodology has been presented to predict the variable interfacial heat flux of a three-dimensional mould domain by assuming the general quadratic profile for heat flux variation and estimating the parameters of a characteristic heat flux profile with the SSA. This methodology uses only the limited experimental data or on-site plant recorded data and hence, it consumes relatively less computational and experimental resources. Representative cases of billet and slab moulds have been considered for numerical analysis using experimental data obtained by the industries. Results indicate that the mould corner heat flux is considerably different from that of the assumed value of 67 % of the literature with deviation reaching as high as 56 % near the meniscus for a slab casting mould.

Subsequently, the methodology is extended to the thin slab continuous casting mould for the estimation of heat flux at the interface of the mould and liquid metal. The mould considered in this work is an industrial funnel-shaped mould having a complex arrangement of cooling holes and slots. Significant variations of heat flux are observed along the casting direction, as well as in other directions. The non-linear behaviour of the heat flux profile is

captured well in the current study, which also leads to a better estimation of the thermal characteristics in the solidifying strand. Heat flux variation as high as 77% relative to wide face centre and 85% relative to the maximum heat flux zone was observed in the corner region. This study also explored the minimum number of sensors to be placed inside the funnel-shaped mould for accurate estimation of the interfacial heat flux.